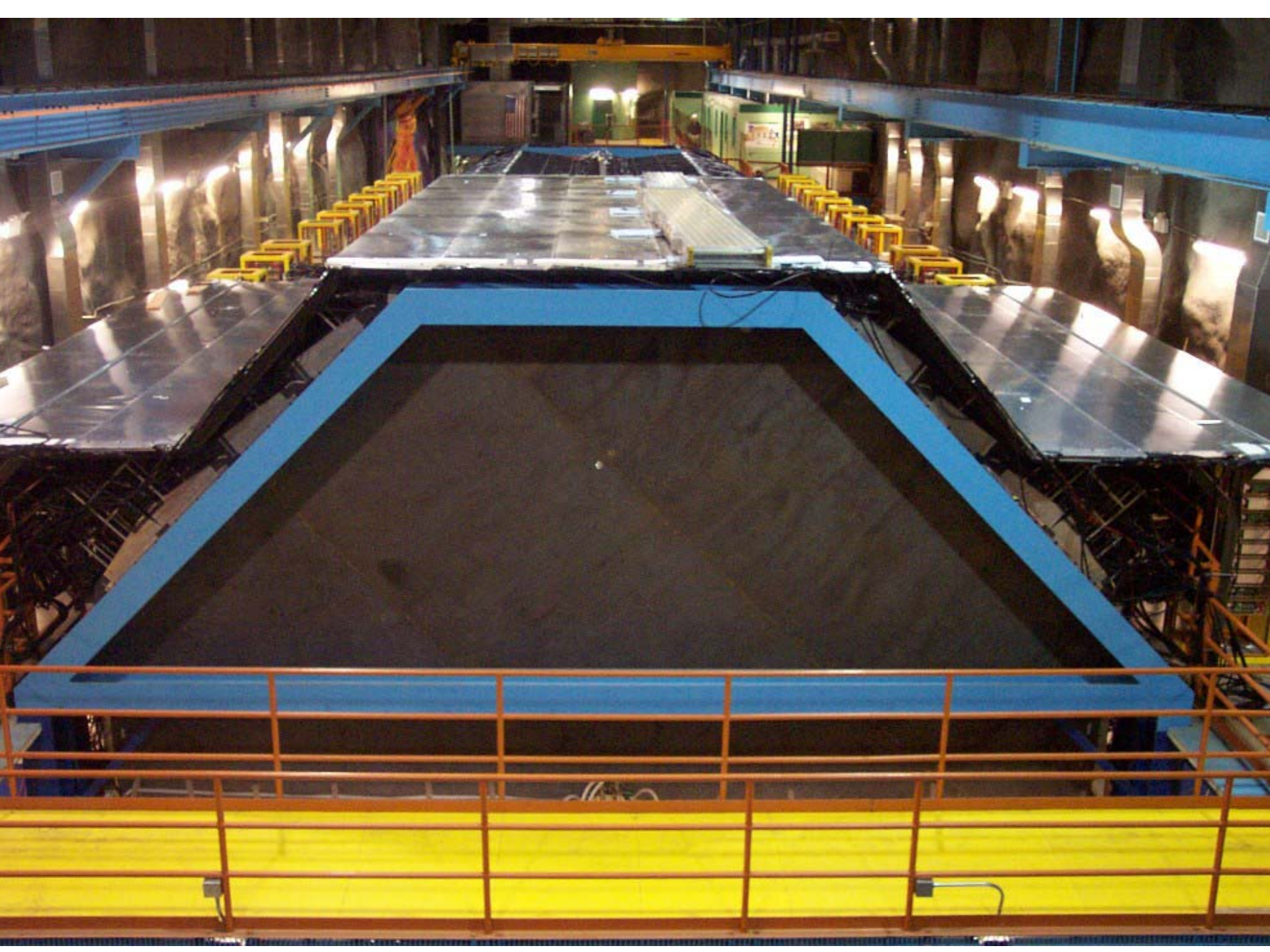


Veto Shield Performance + Atmospheric Neutrino Data Analysis

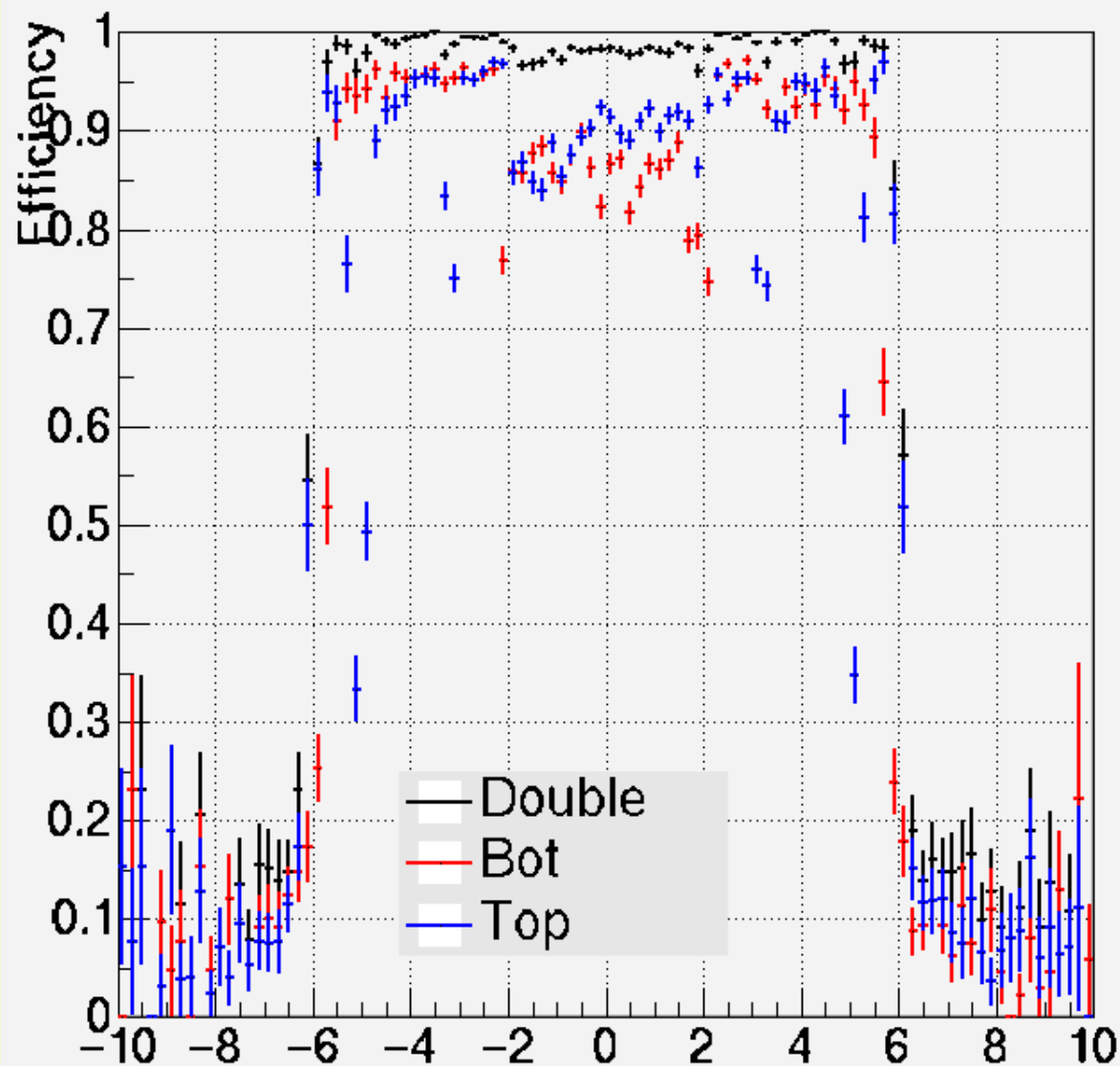
Roy Lee
MINOS Collaboration Meeting
September 2002



Shield Efficiency vs X Position

$0.5 < \text{projz} < 7.5 \text{ m}$

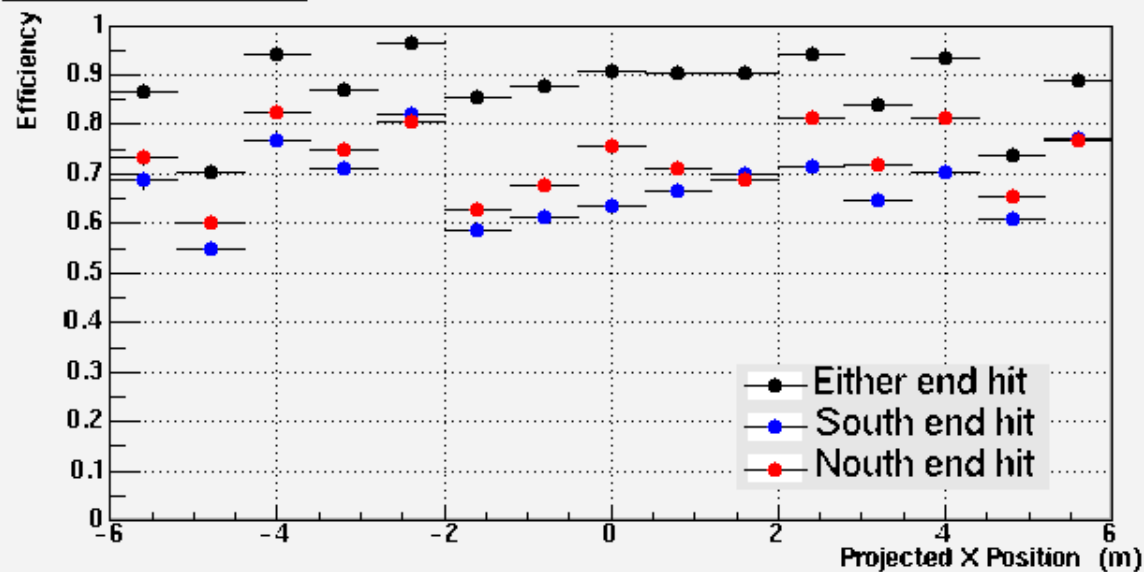
Shield Efficiency vs Projected X Position



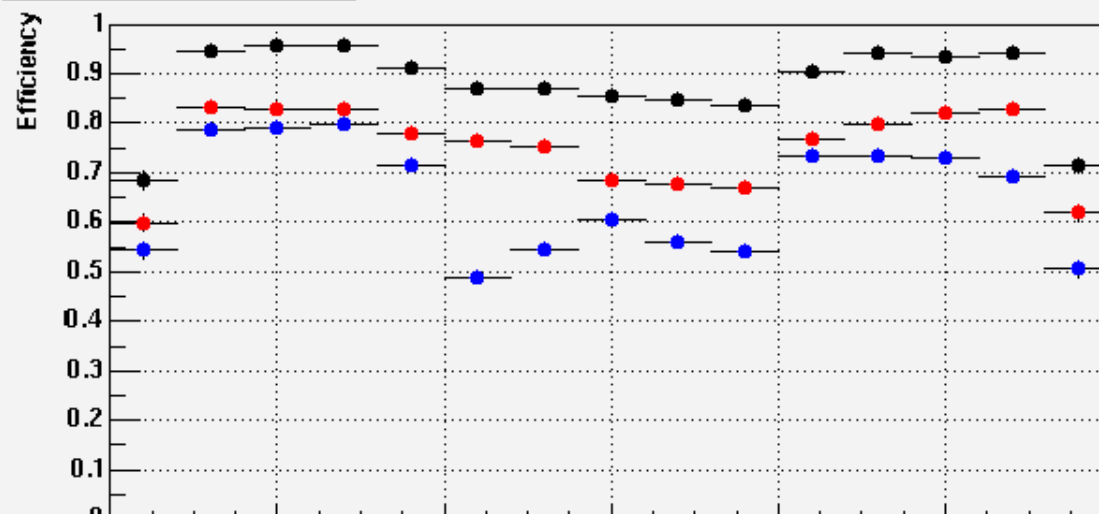
Single Layer Efficiency vs X

$0.5 < \text{projz} < 7.5 \text{ m}$

Top Layer Efficiency



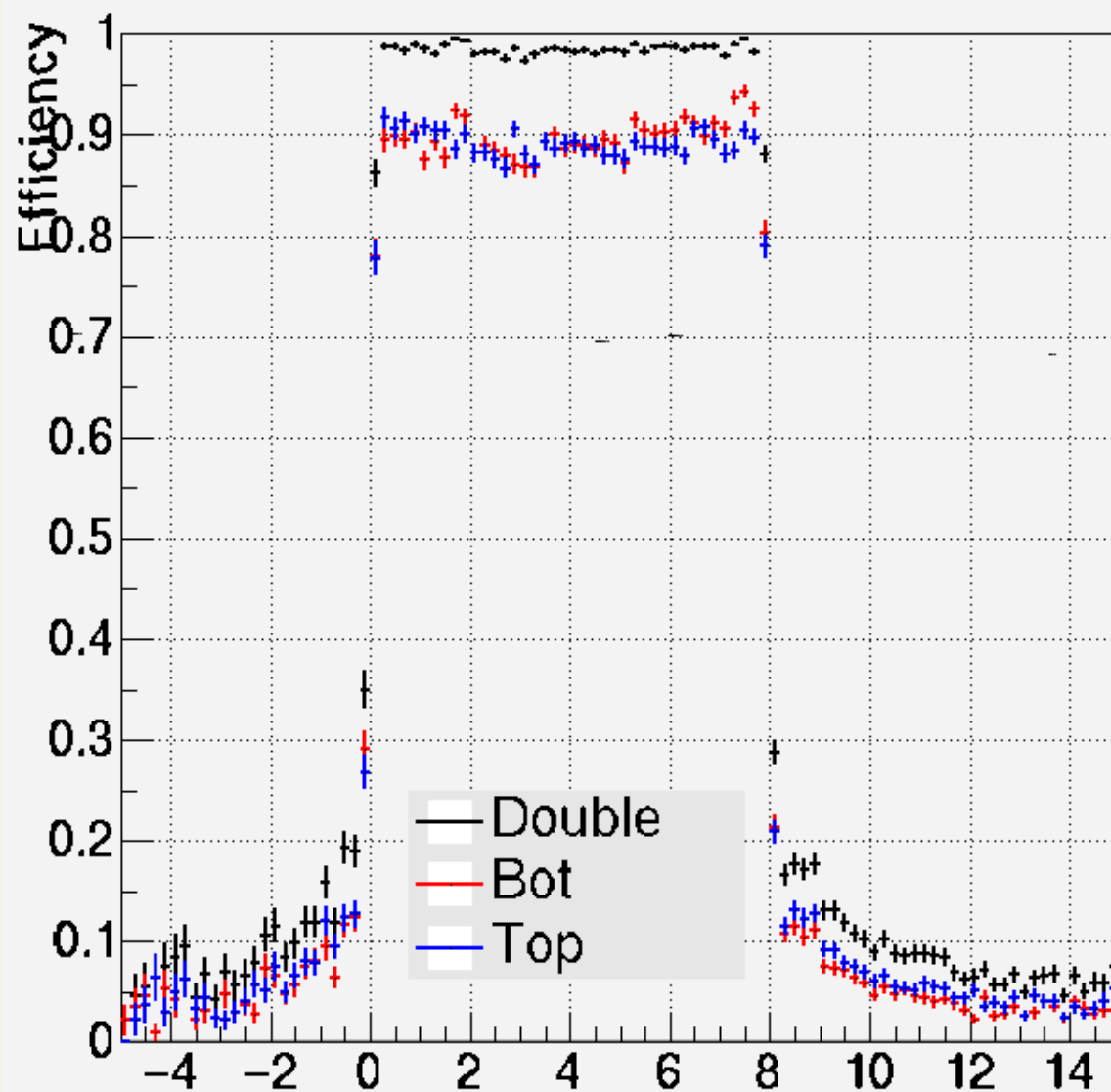
Bottom Layer Efficiency



Shield Efficiency vs Z Position

$-5.5 < \text{projx} < +5.5 \text{ m}$

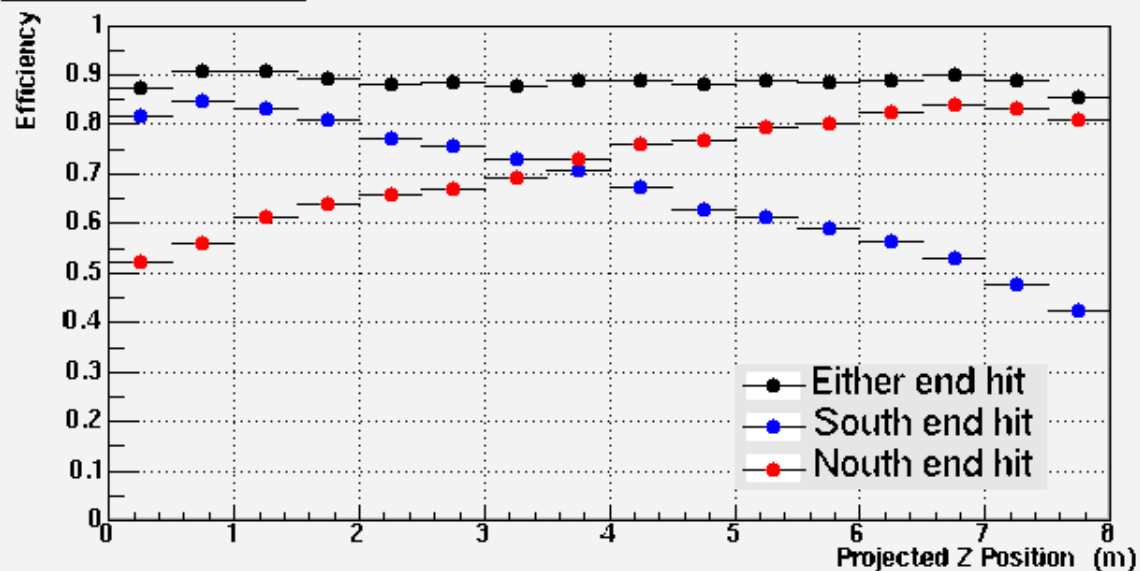
Shield Efficiency vs Projected Z Position



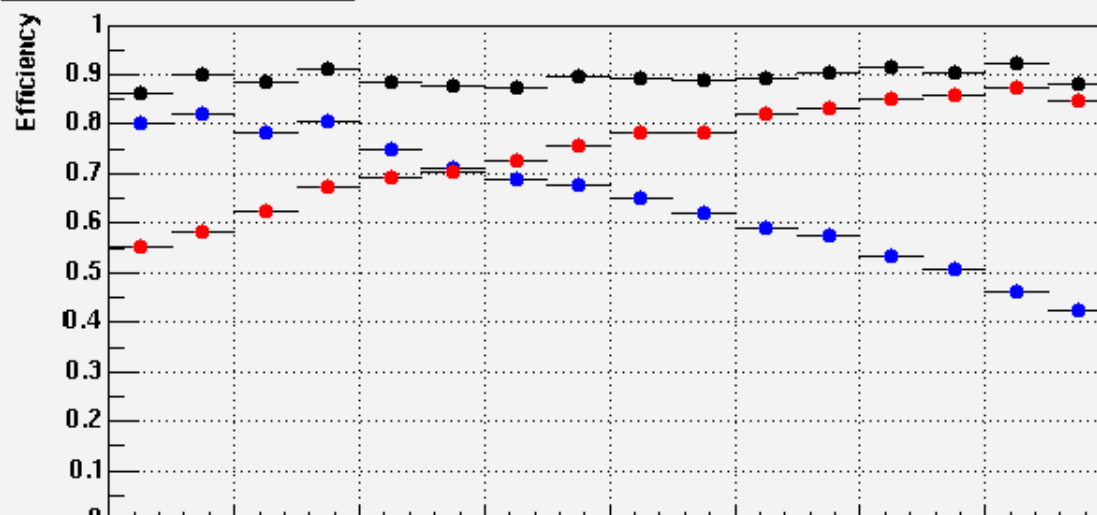
Single Layer Efficiency vs Z

$-5.5 < \text{proj}x < +5.5 \text{ m}$

Top Layer Efficiency



Bottom Layer Efficiency

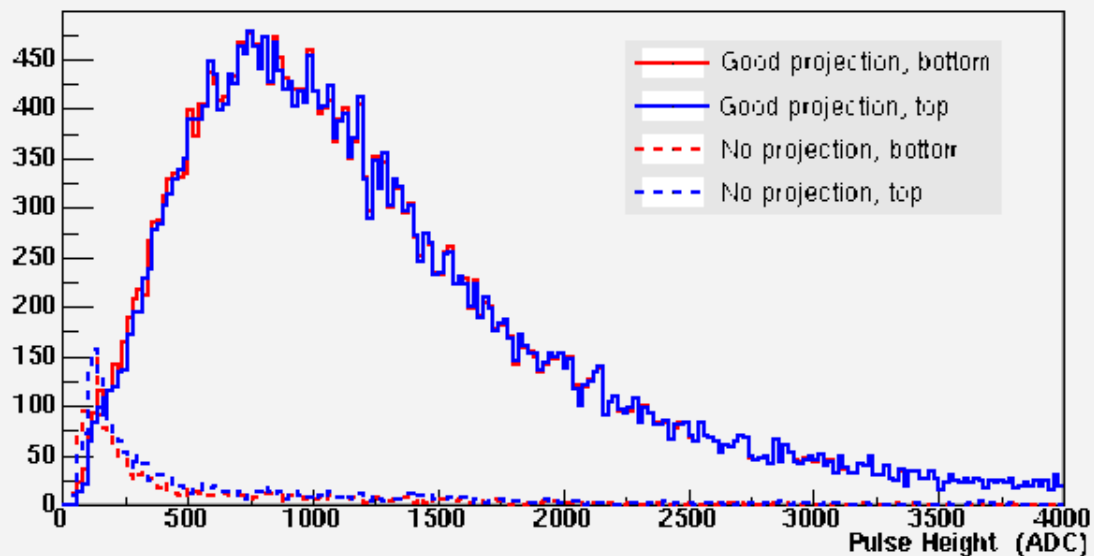


Shield Pulse Height

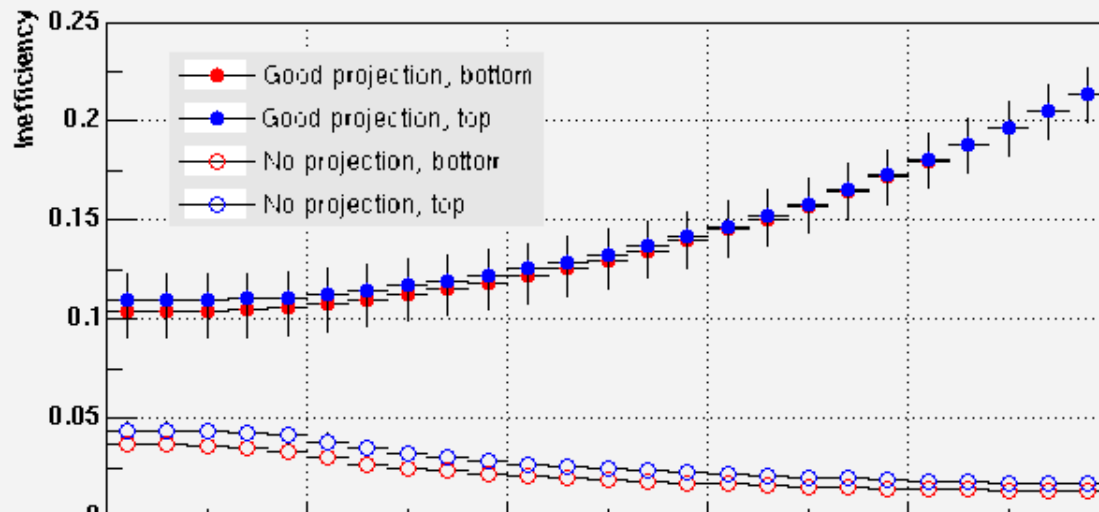
Good shield projection: $-5.5 < \text{projx} < +5.5$ m, $0.5 < \text{projz} < 7.5$ m

No shield projection: $\text{projz} > 9.0$ m

Veto Shield Pulse Height



Veto Shield Pulse Height

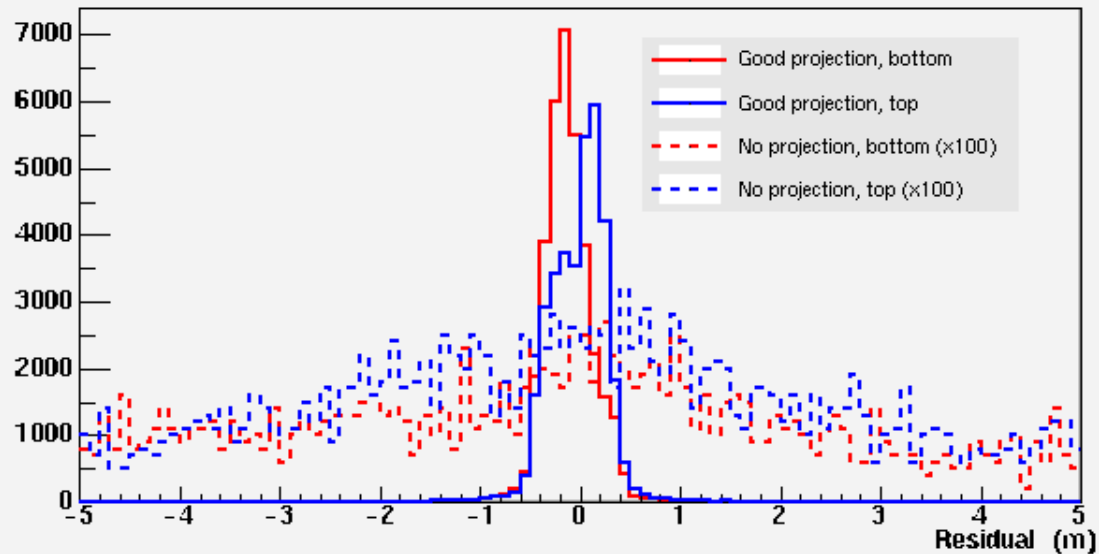


Shield Spatial Residuals

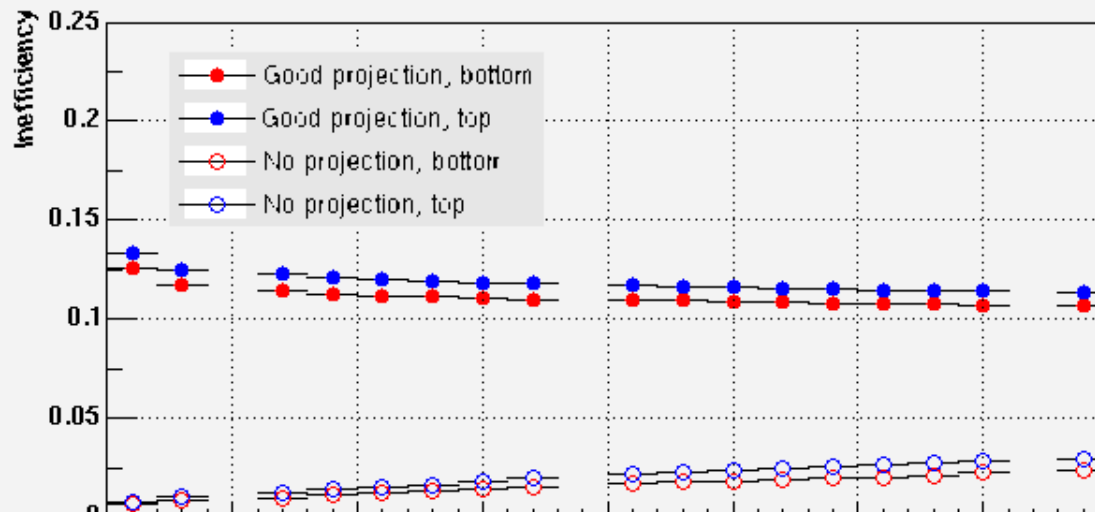
Good shield projection: $-5.5 < \text{projx} < +5.5$ m, $0.5 < \text{projz} < 7.5$ m

No shield projection: $\text{projz} > 9.0$ m

X Position Residual



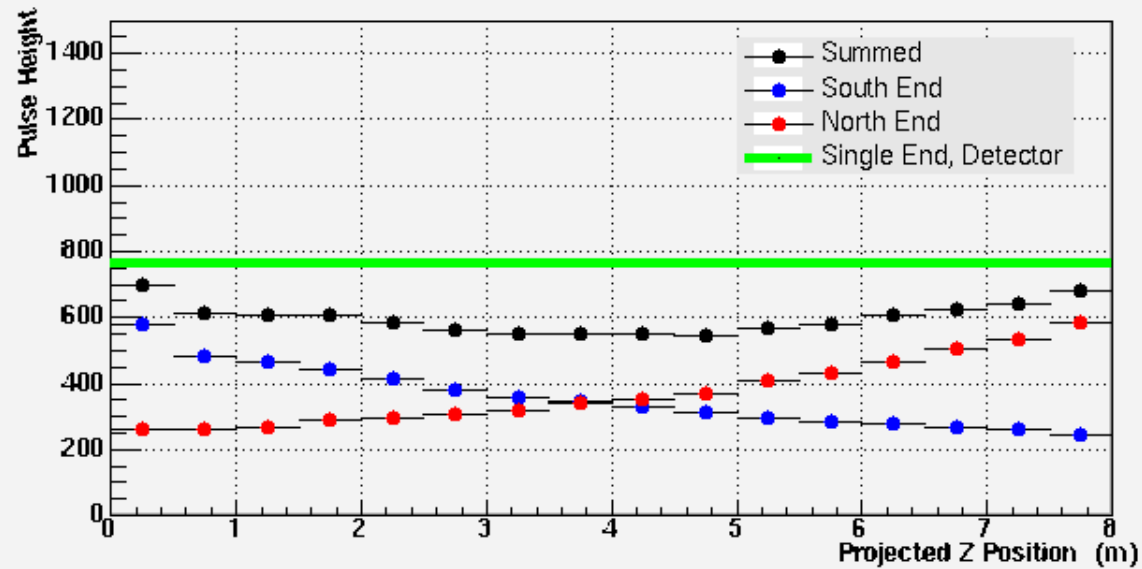
X Position Residual



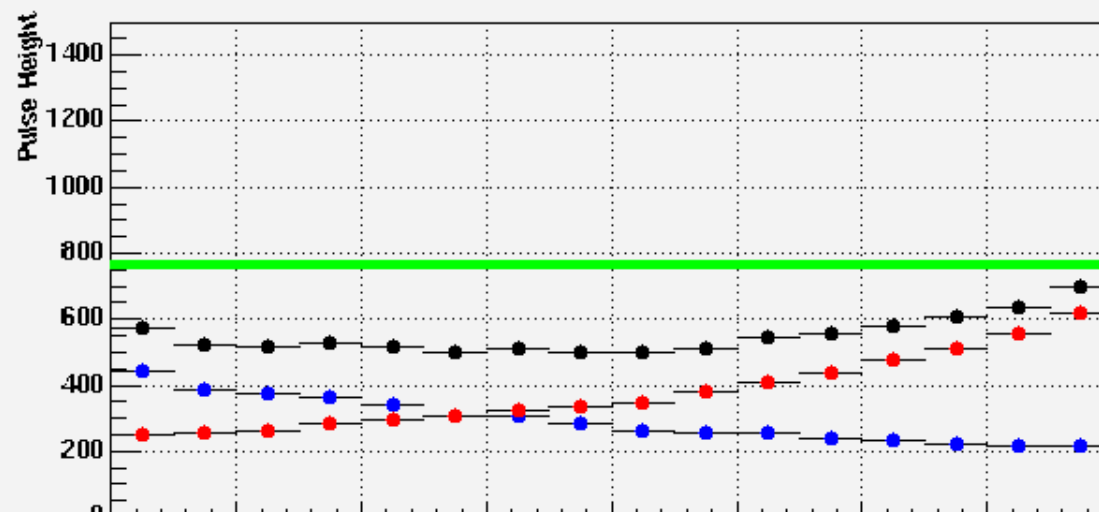
Raw Shield Pulse Height vs Z

$-5.5 < \text{proj}x < +5.5 \text{ m}$

Top Layer Pulse Height



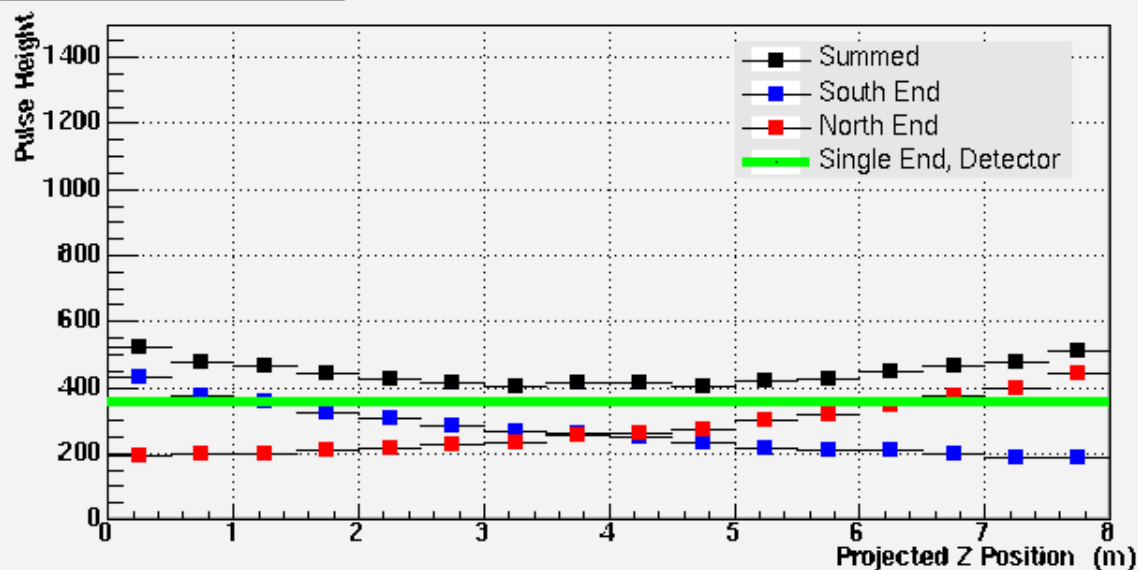
Bottom Layer Pulse Height



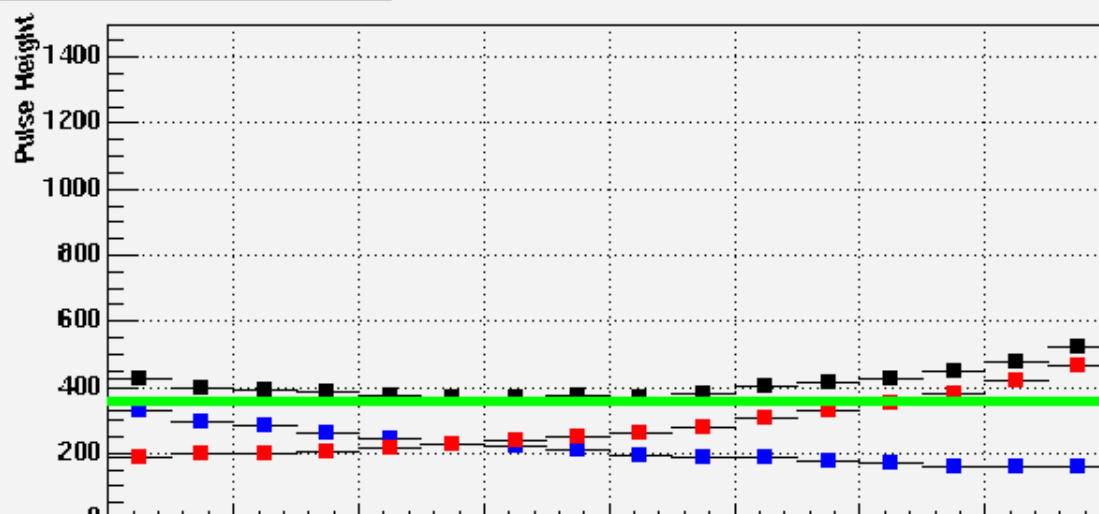
Angle Corrected Shield Pulse Height vs Z

$-5.5 < \text{projx} < +5.5 \text{ m}$

Top Layer Pulse Height



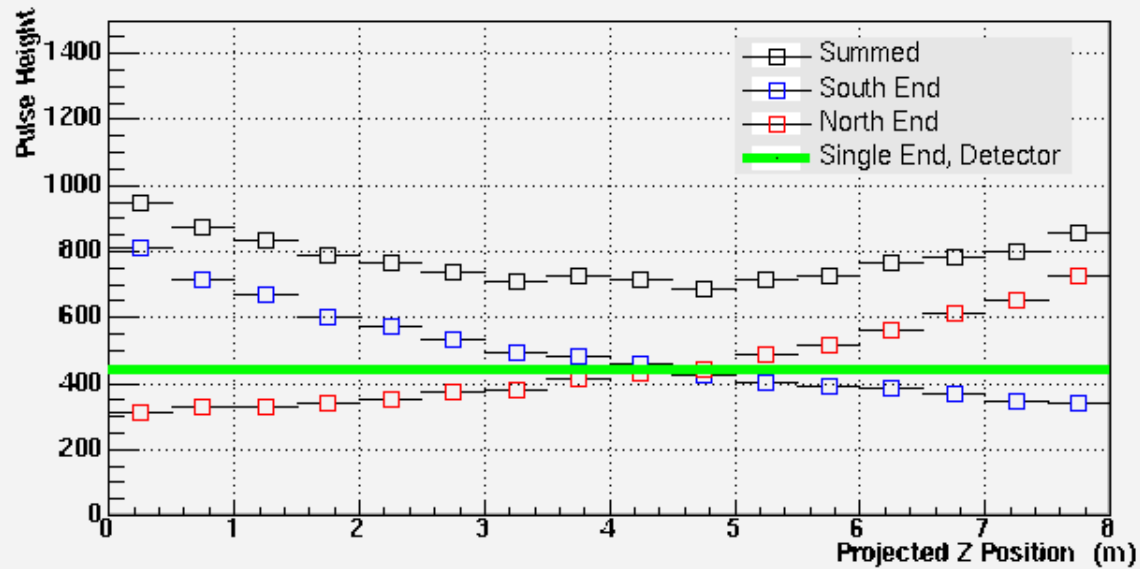
Bottom Layer Pulse Height



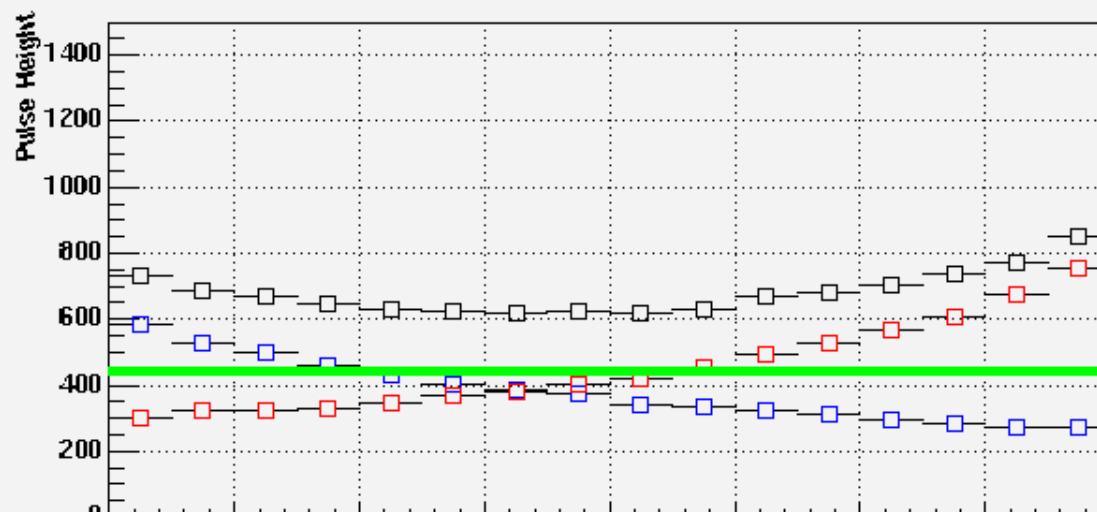
Shield Pulse Height vs Z

$-5.5 < \text{proj}x < +5.5 \text{ m}$

Top Layer Pulse Height



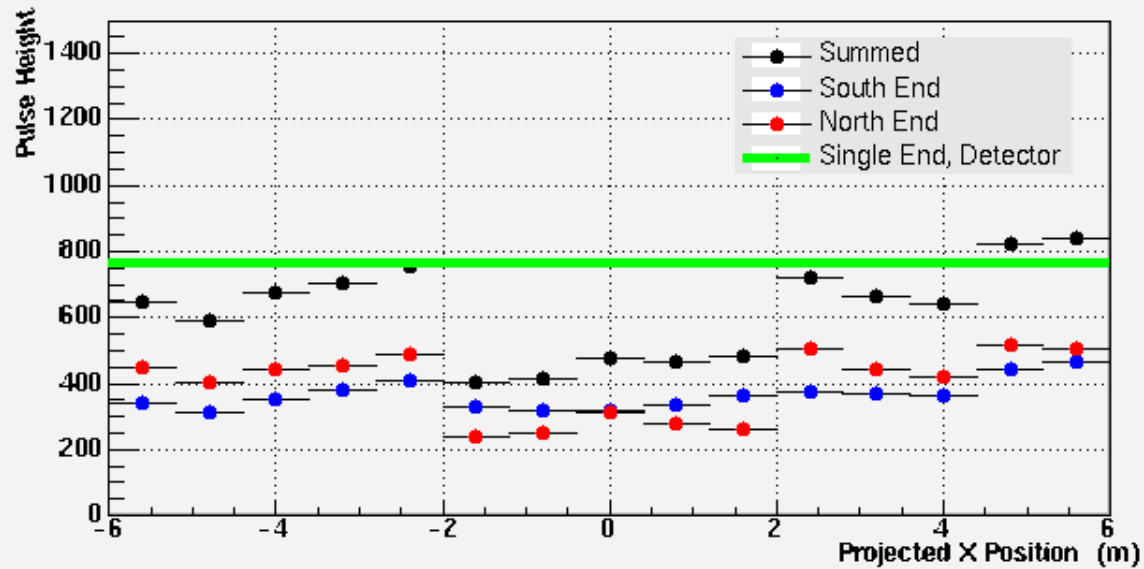
Bottom Layer Pulse Height



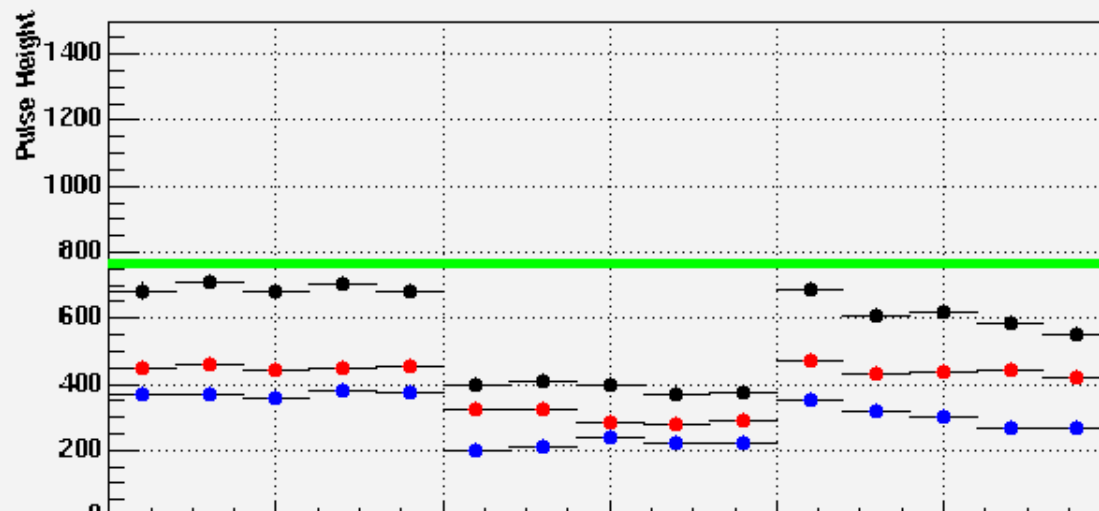
Raw Shield Pulse Height vs X

$0.5 < \text{projz} < 7.5 \text{ m}$

Top Layer Pulse Height



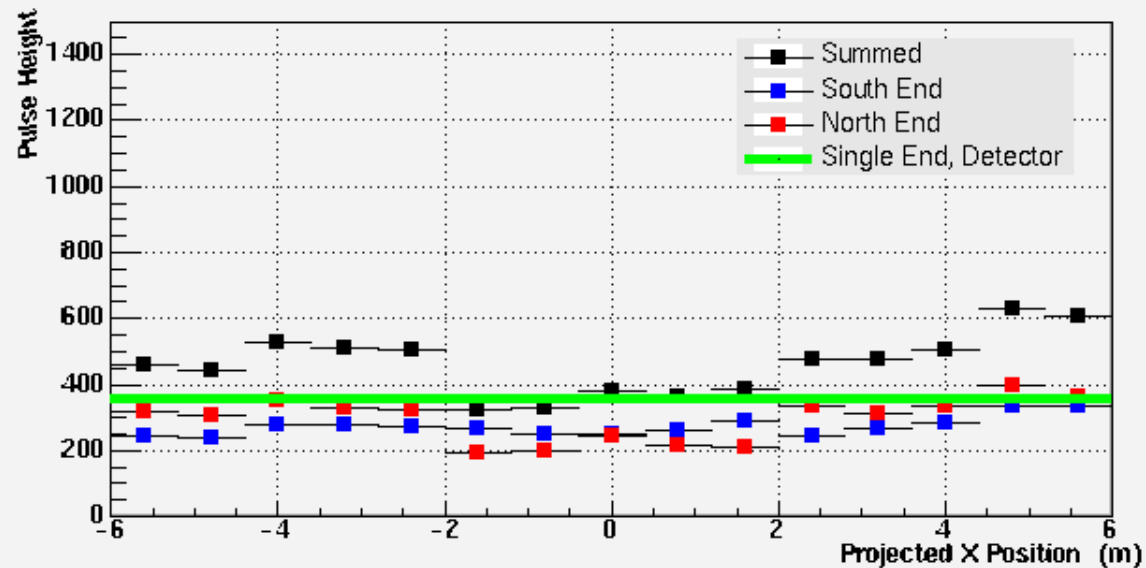
Bottom Layer Pulse Height



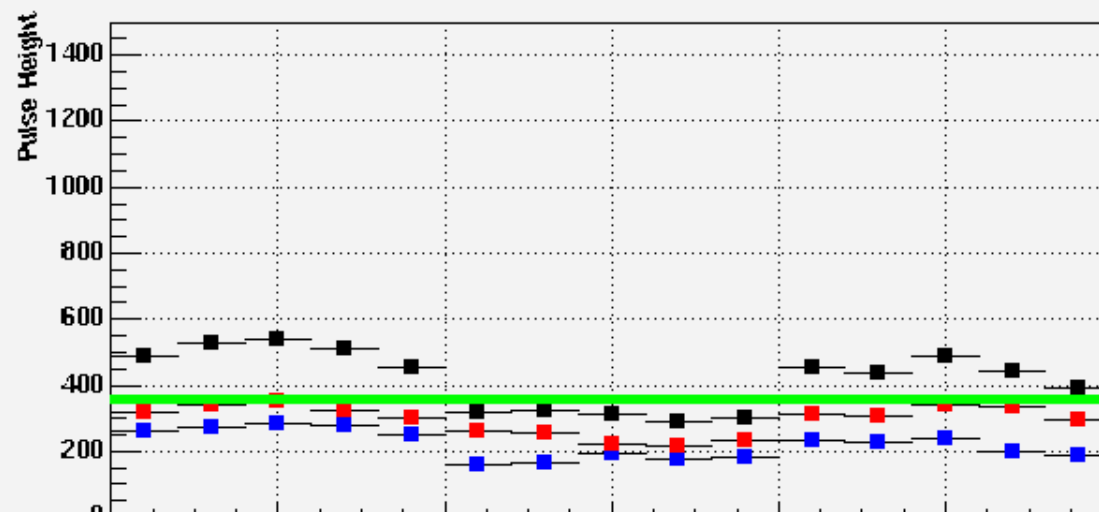
Angle Corrected Shield Pulse Height vs X

$0.5 < \text{projz} < 7.5 \text{ m}$

Top Layer Pulse Height



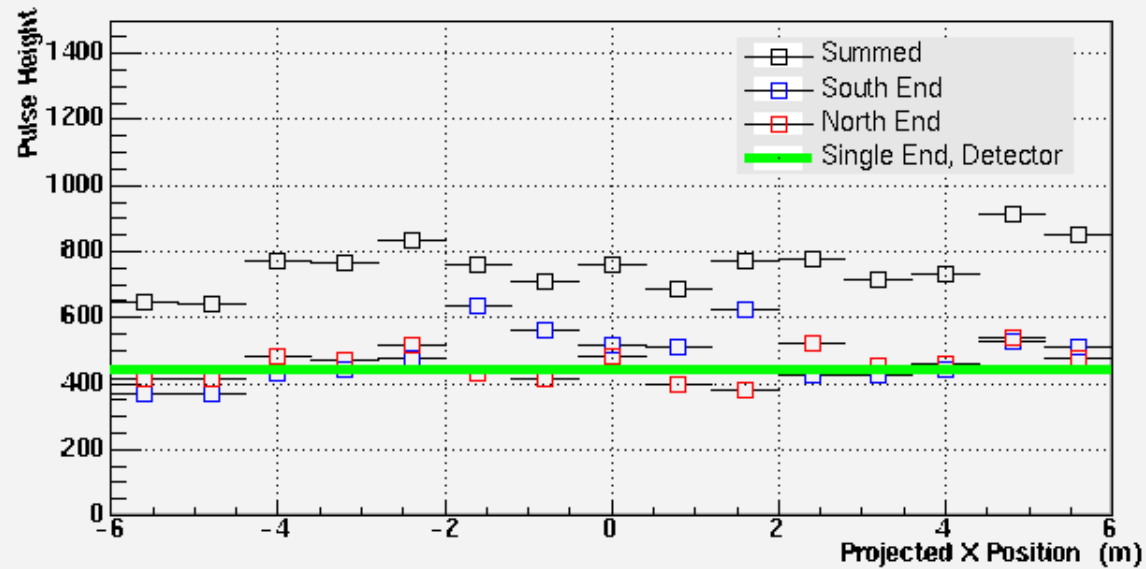
Bottom Layer Pulse Height



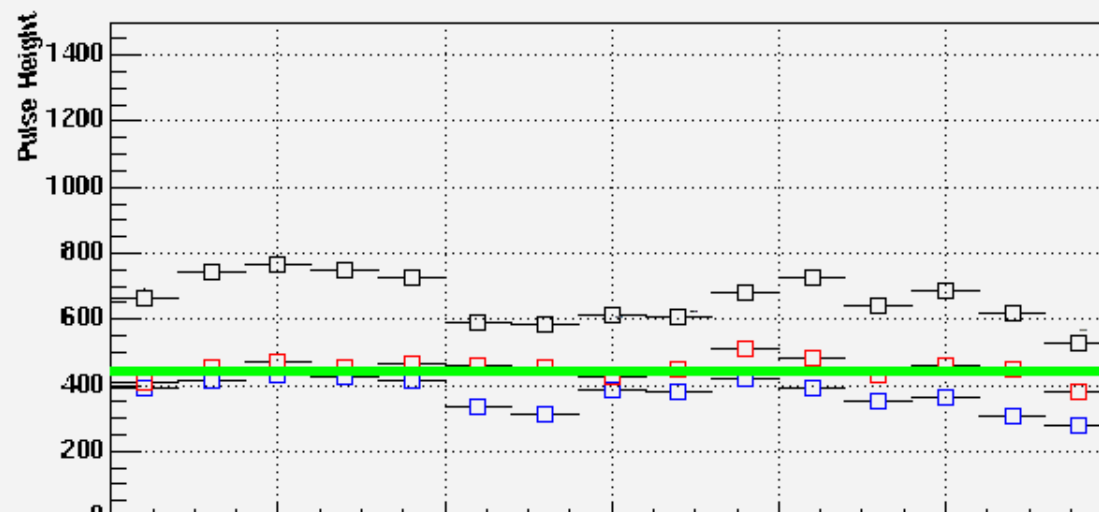
Angle + Clear Fiber Corrected Shield Pulse Height vs X

$0.5 < \text{projz} < 7.5 \text{ m}$

Top Layer Pulse Height

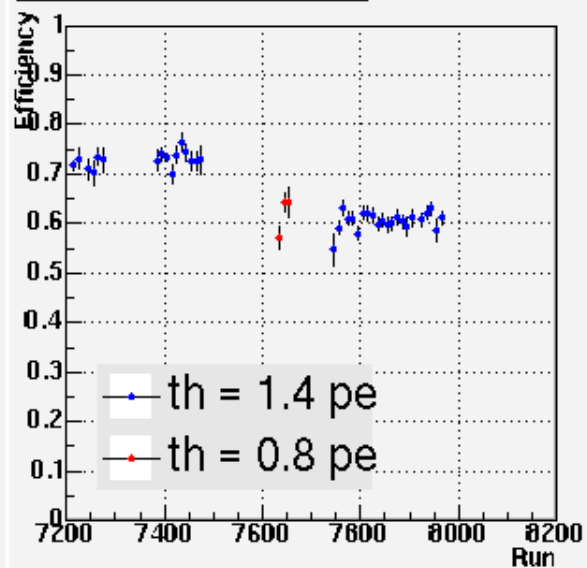


Bottom Layer Pulse Height

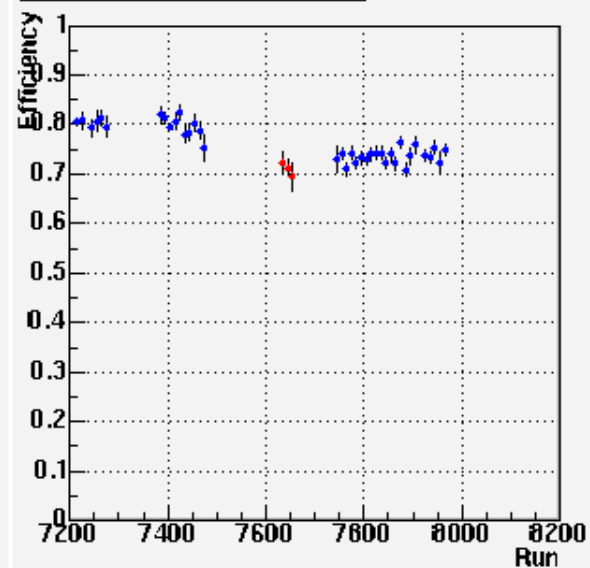


Shield Efficiency vs Run

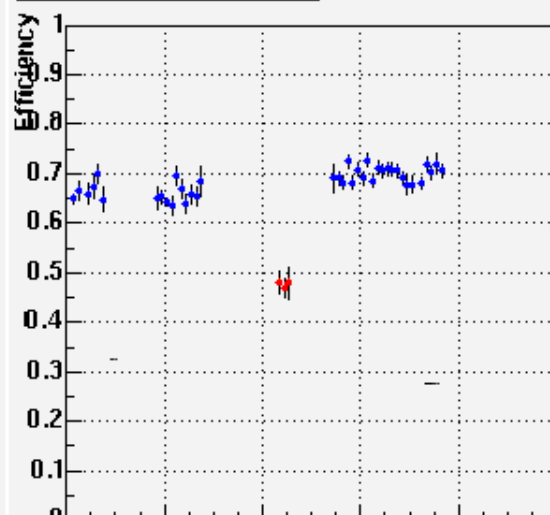
Bottom Layer, South End



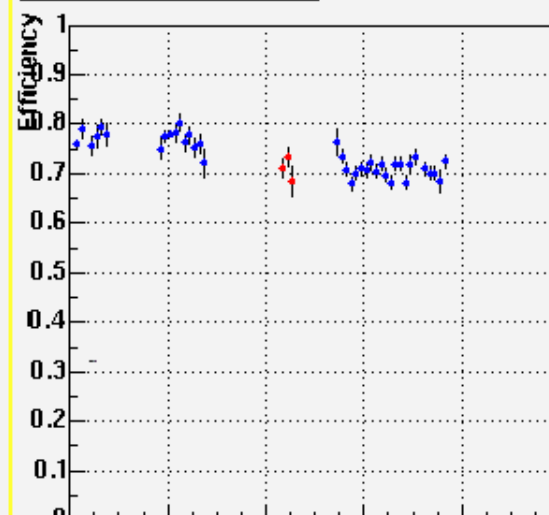
Bottom Layer, North End



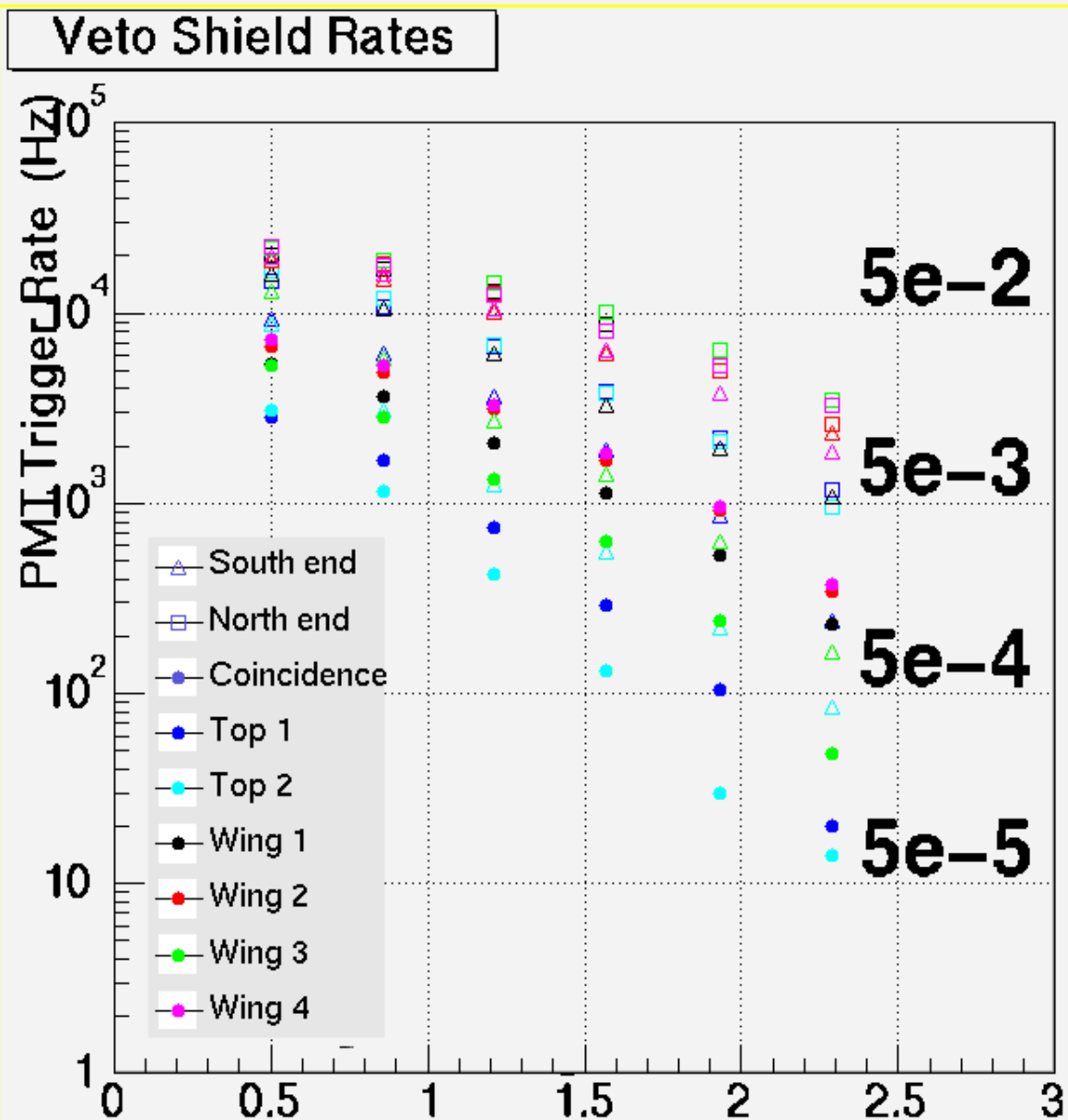
Top Layer, South End



Top Layer, North End

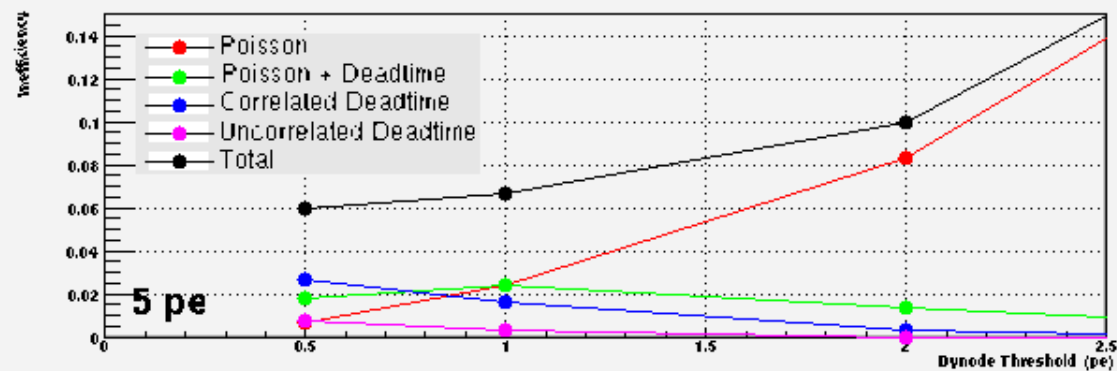


Veto Shield Rates

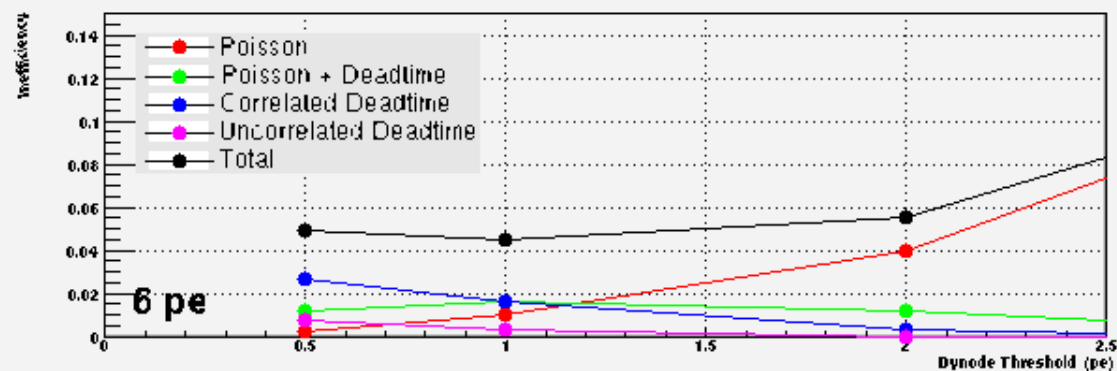


Shield Background Rates and Pulse Height

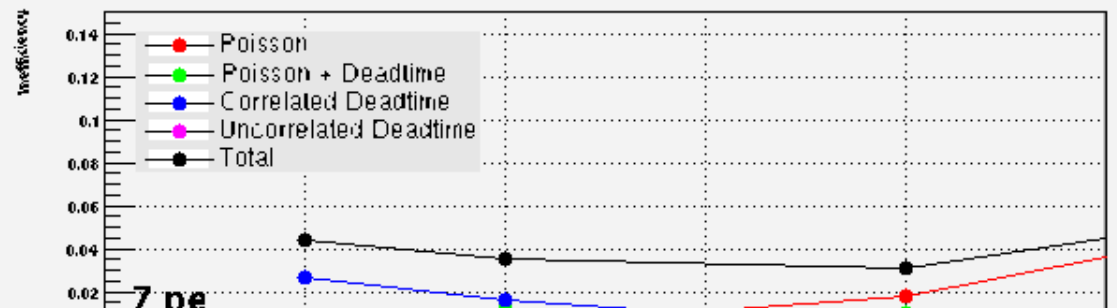
Single Layer efficiency, summed light yield = 5 pe



Single Layer efficiency, summed light yield = 6 pe

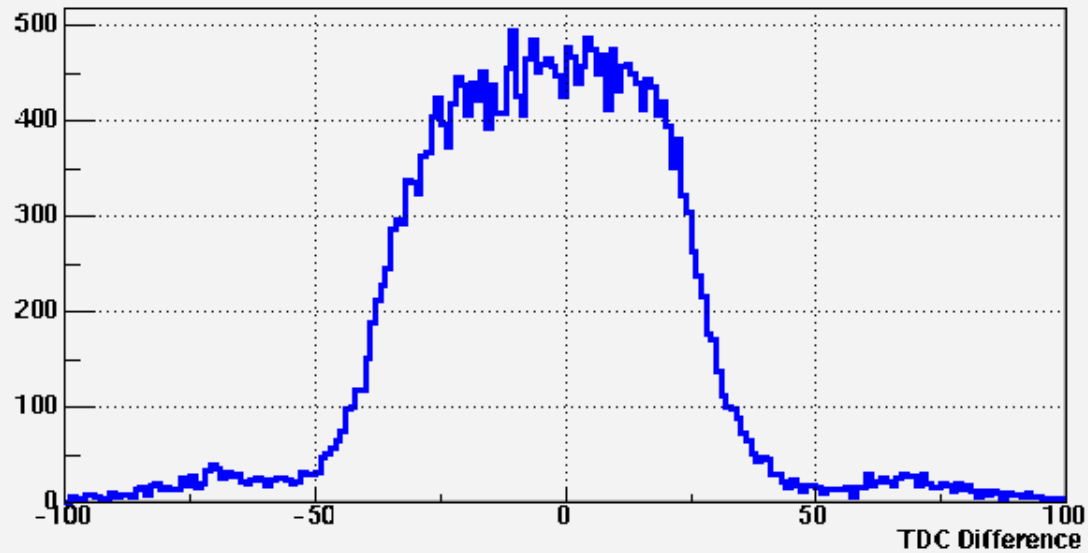


Single Layer efficiency, summed light yield = 7 pe

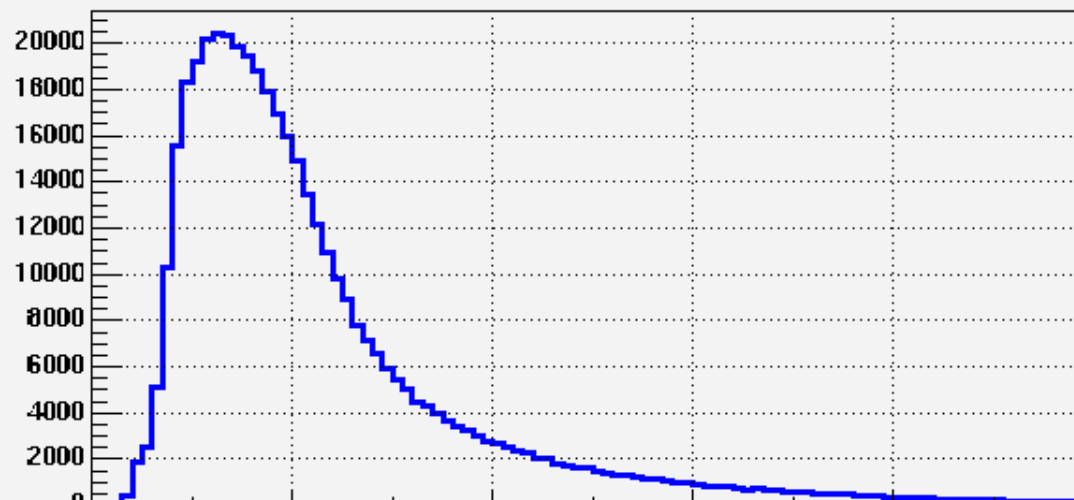


Shield Background Rates and Pulse Height

Shield Strip End Coincidence



Shield Single Ended Pulse Height

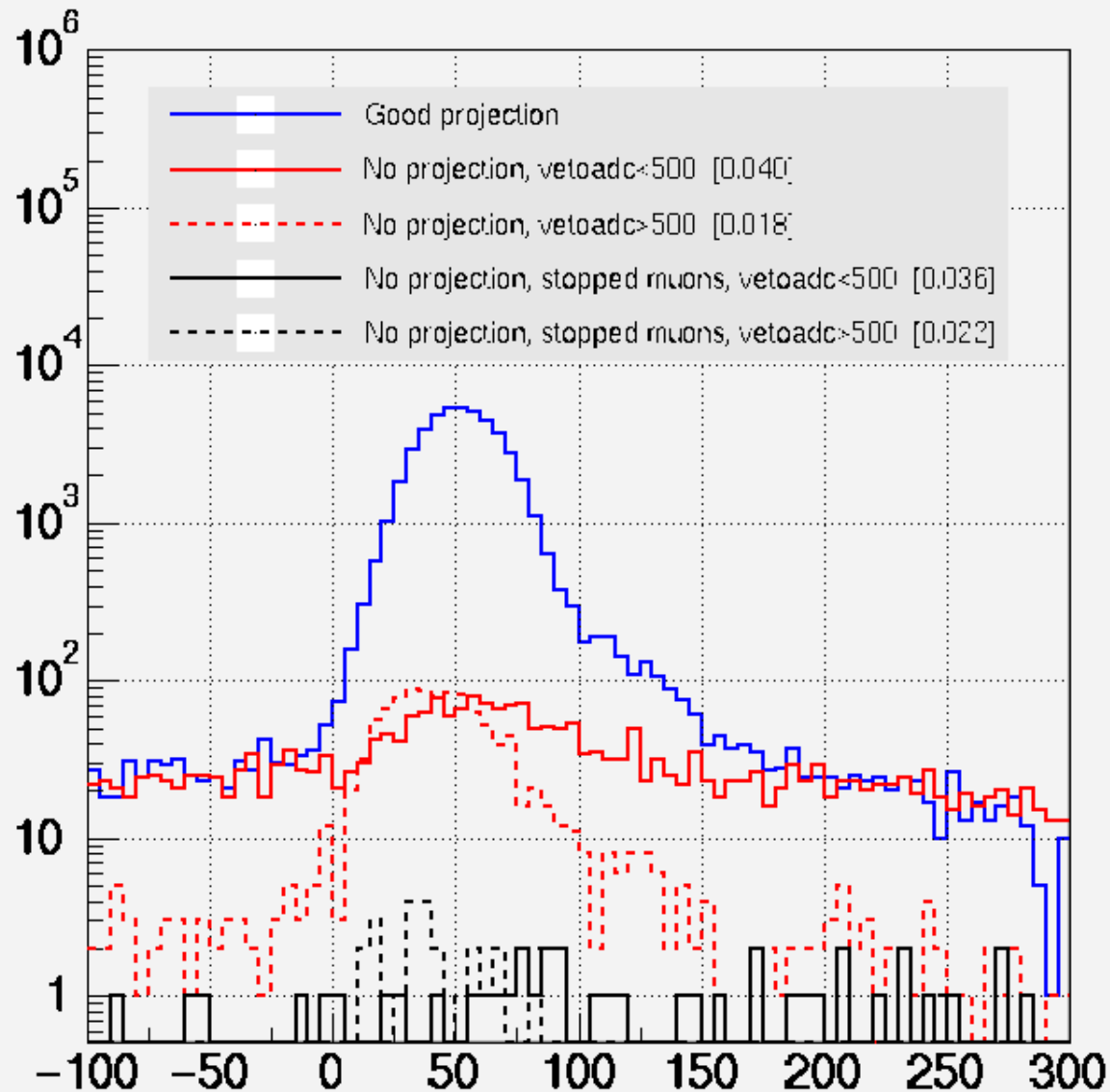


Shield Timing

Good shield projection: $-5.5 < \text{projx} < +5.5$ m, $0.5 < \text{projz} < 7.5$ m

No shield projection: $\text{projz} > 9.0$ m

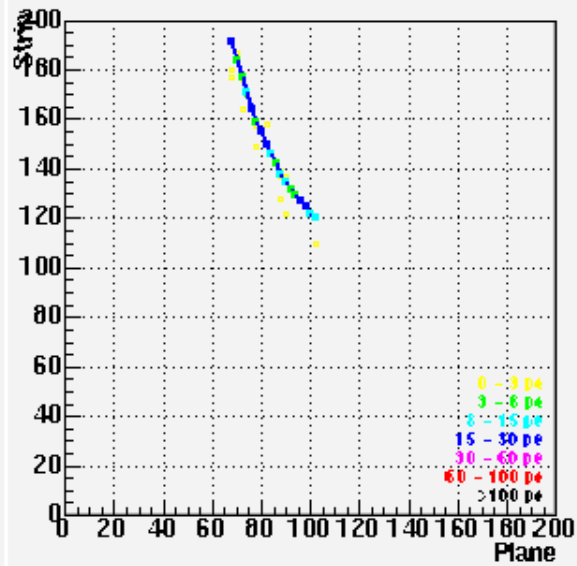
Veto Shield Time (Earliest Digit)



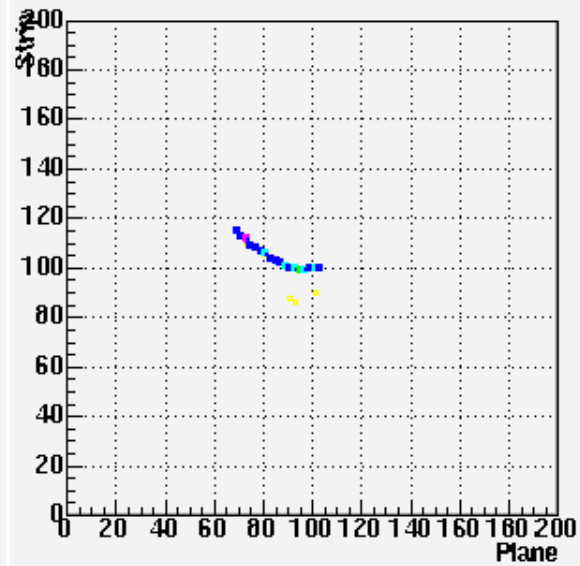
Run 7210, Snarl 37

Vertex: (x,y,z) = (2.2, 3.4, 4.0)

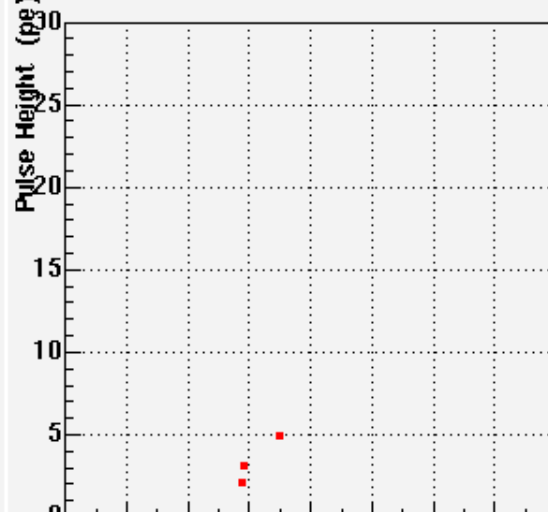
u-view



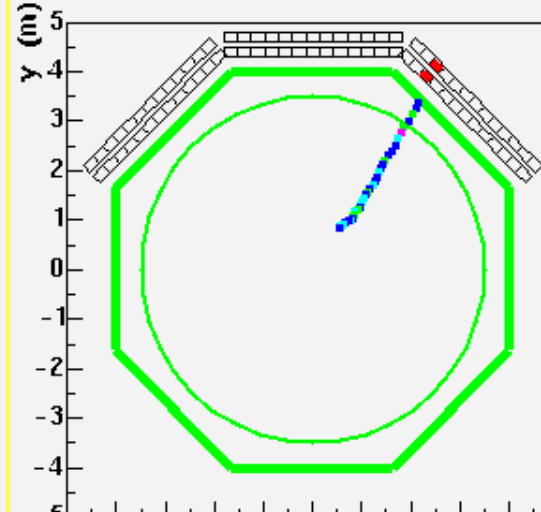
v-view



Shield Digits



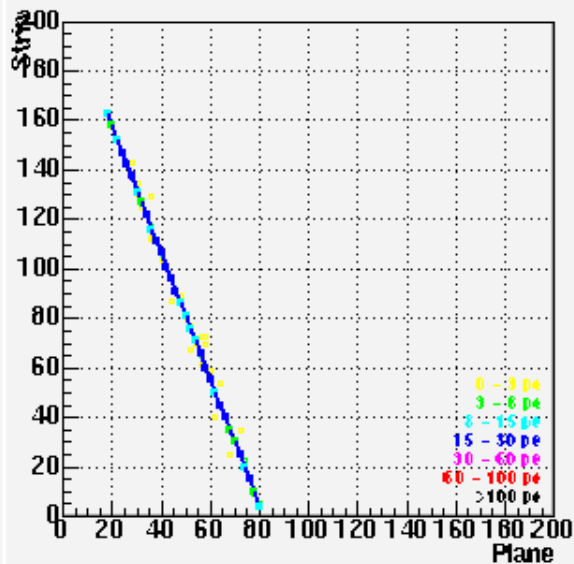
Face On View



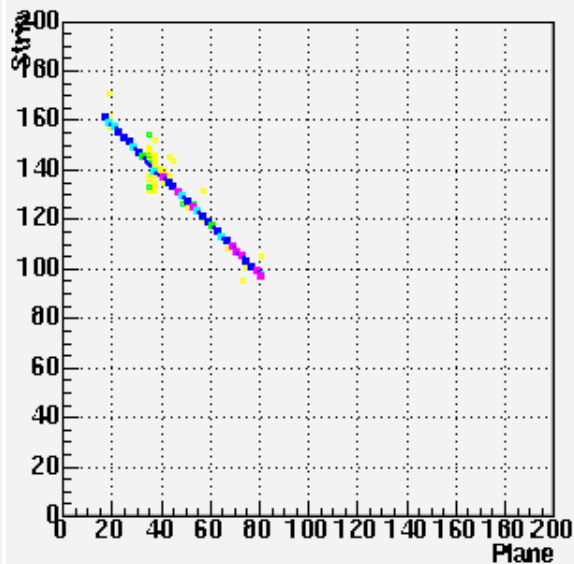
Run 7210, Snarl 972

Vertex: (x,y,z) = (0.1, 3.9, 1.0)

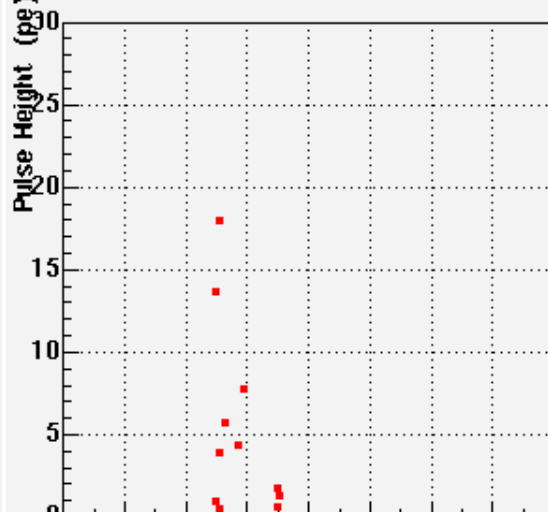
u-view



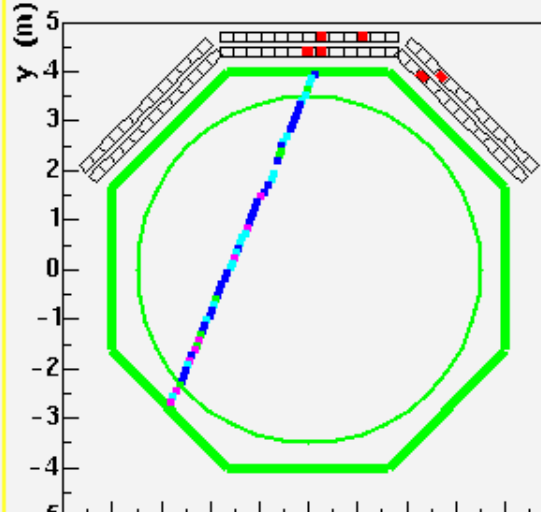
v-view



Shield Digits



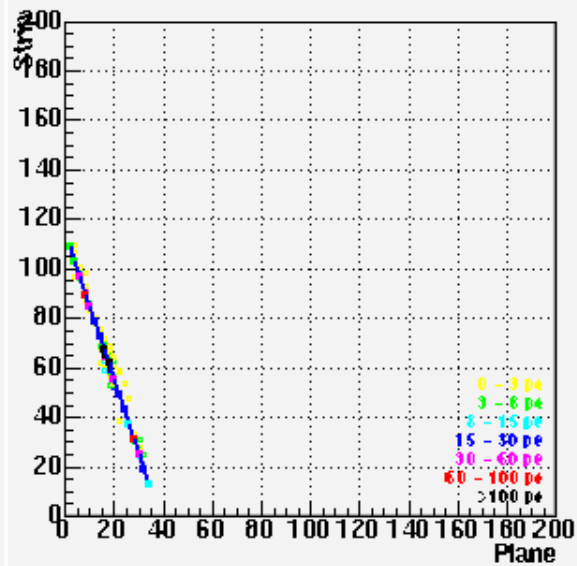
Face On View



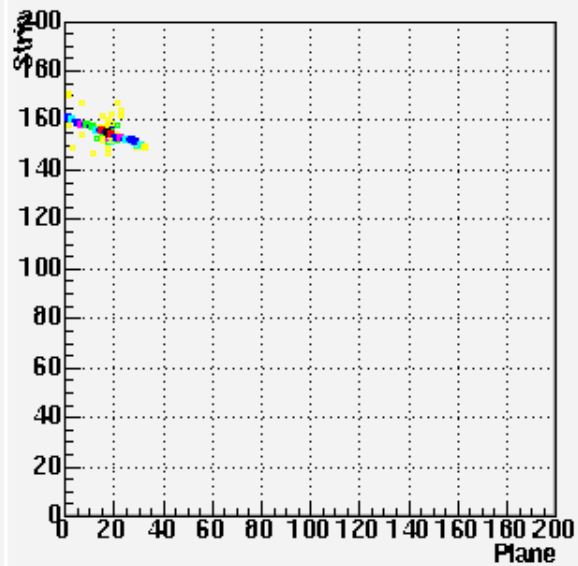
Run 7210, Snarl 205

Vertex: (x,y,z) = (-1.4, 2.4, 0.1)

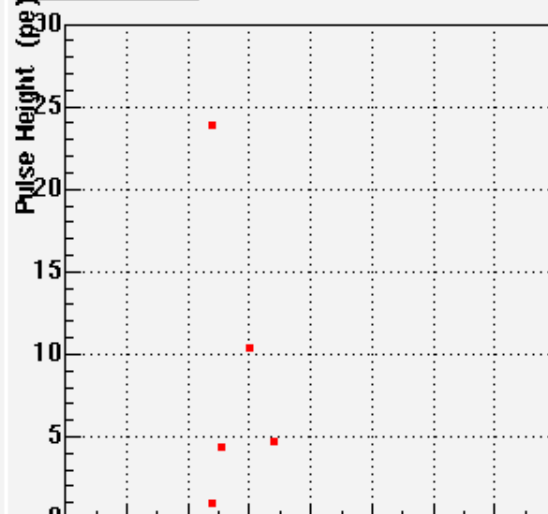
u-view



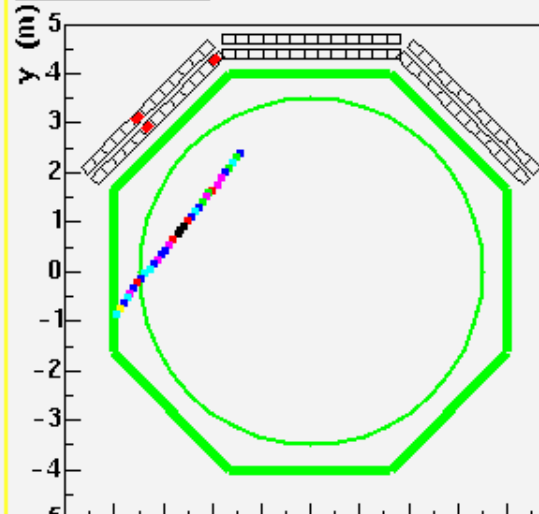
v-view



Shield Digits



Face On View



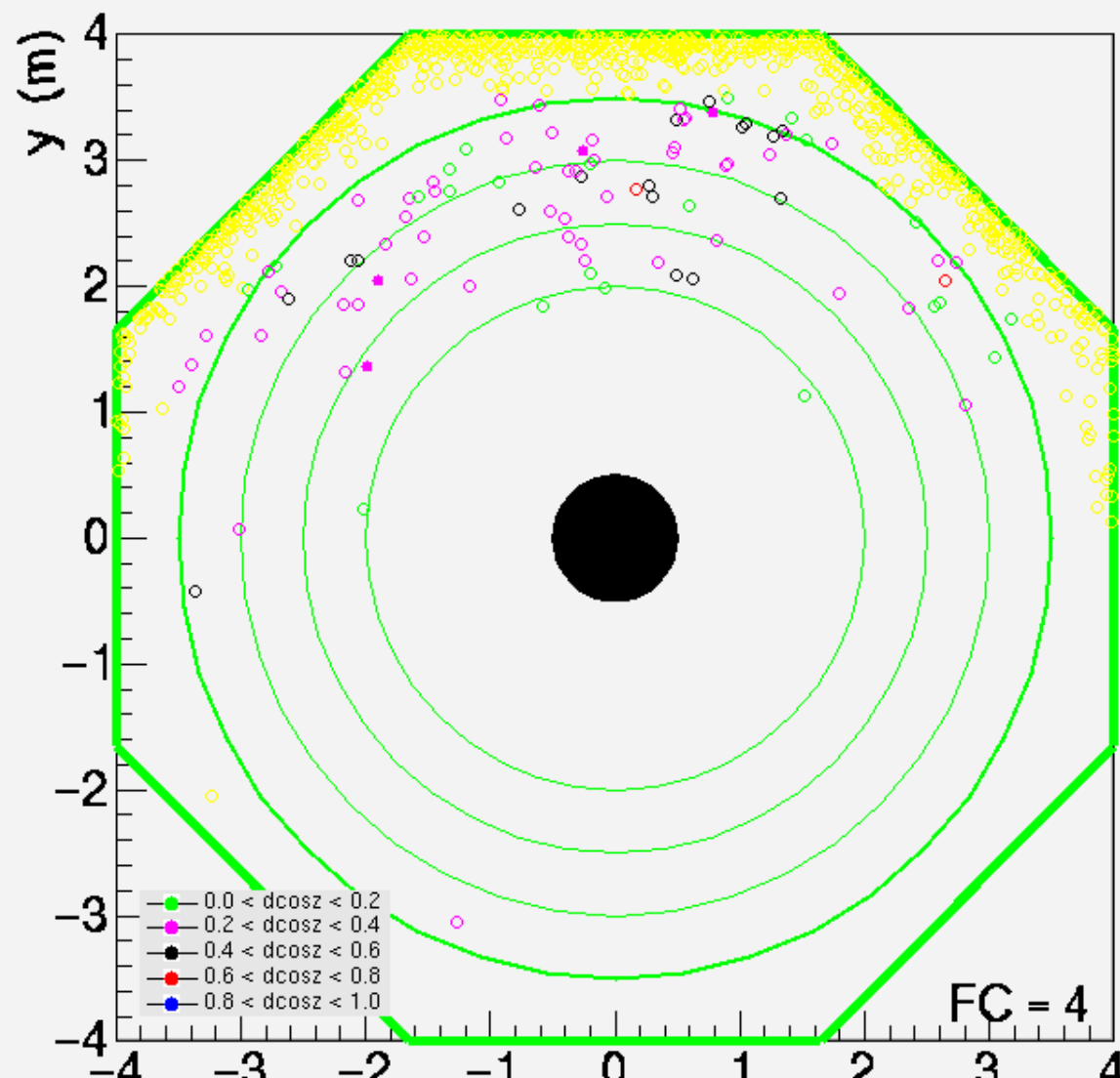
Fully Contained Event Sample

Reconstructed track, end radius < 3.5 m, 10 plane veto

Track must point back to shield

8.6 days livetime, 135 planes shield coverage, 0.6 numu CC expected

Vertex Position, Face On View



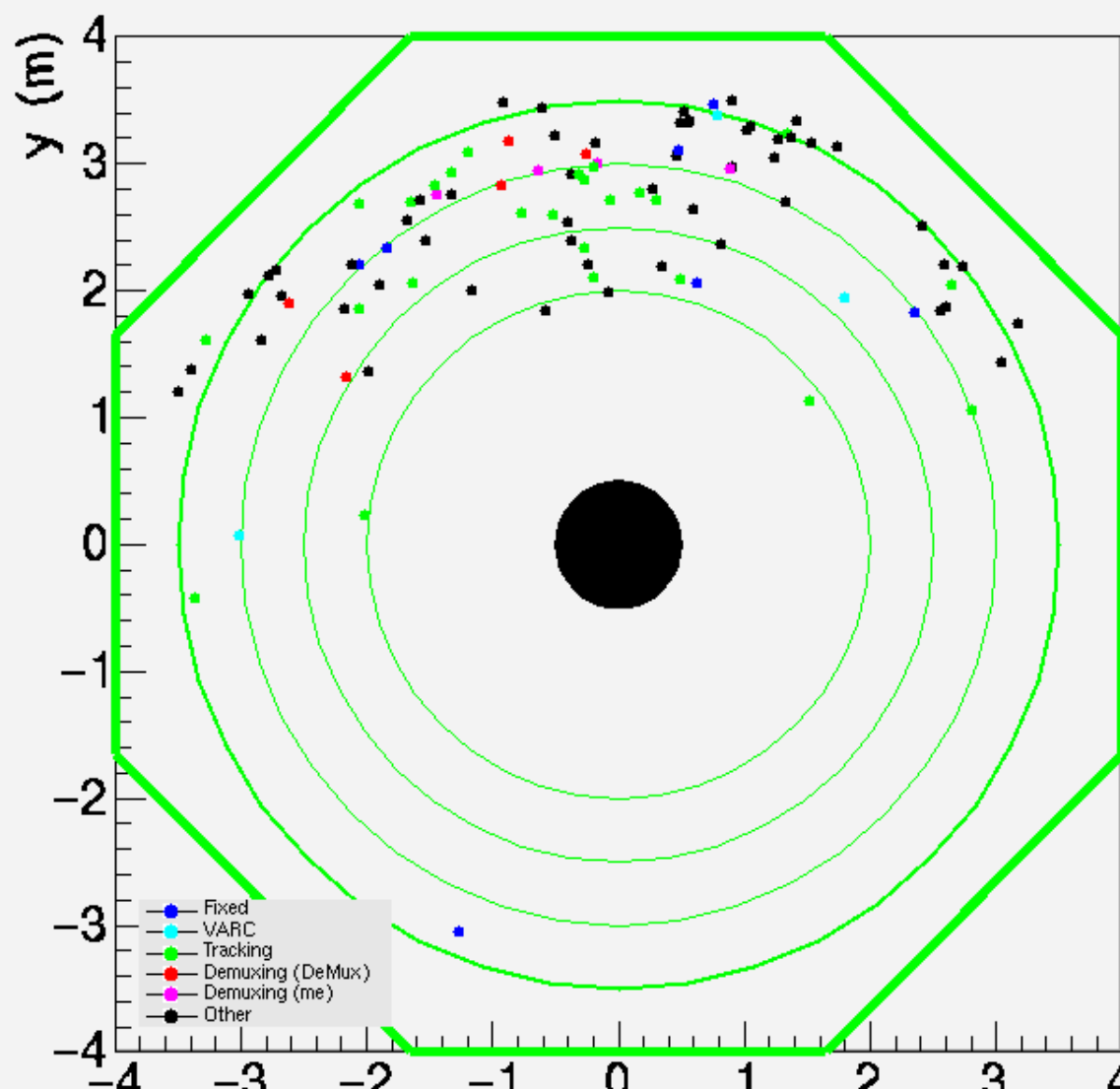
Fully Contained Event Sample

Reconstructed track, end radius < 3.5 m, 10 plane veto

Track must point back to shield

8.6 days livetime, 135 planes shield coverage, 0.6 numu CC expected

Vertex Position, Face On View



Fully Contained Event Classification

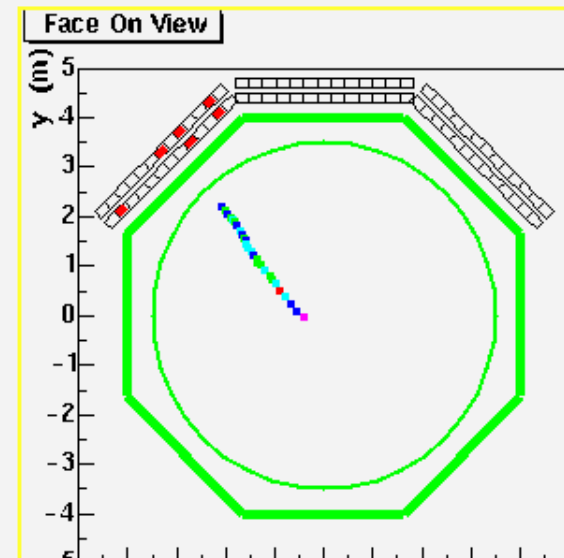
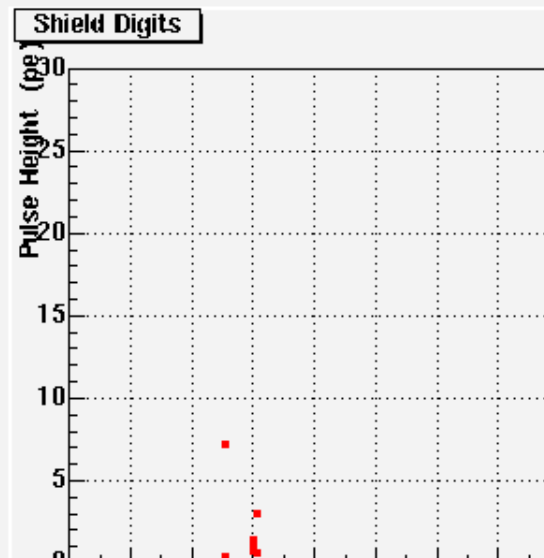
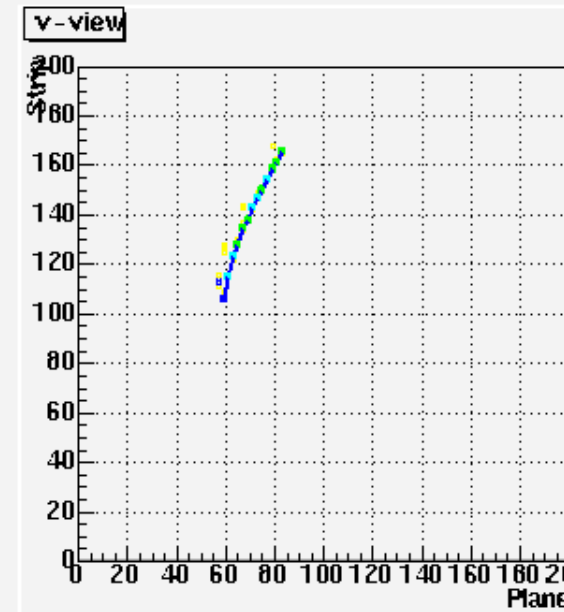
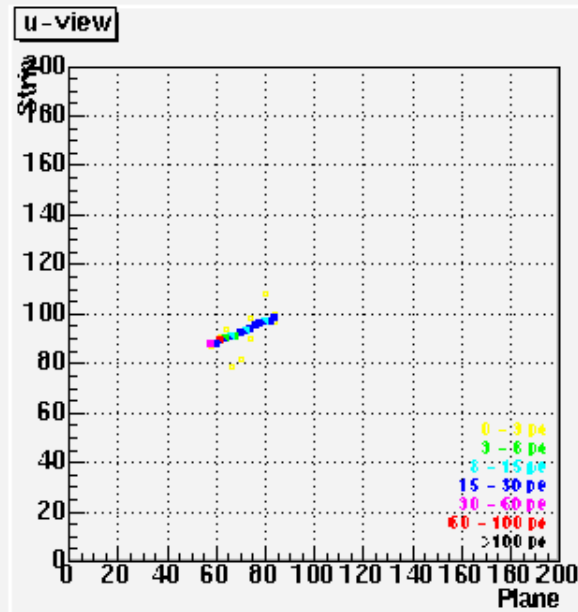
- 98 events that are fully contained
 - 7 fixed with new demuxing
 - 3 at VARC boundary
 - 4 bad tracking
 - 5 bad demuxing (as reported by DeMux)
 - 27 bad demuxing (as reported by me)
 - 52 other

Old Demux

Run 7210, Snarl 4015

z direction cosine = -0.519, $\cos(\text{zenith}) = 0.700$

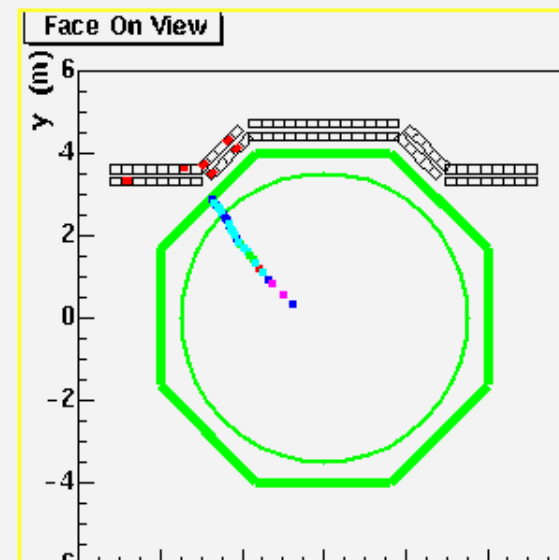
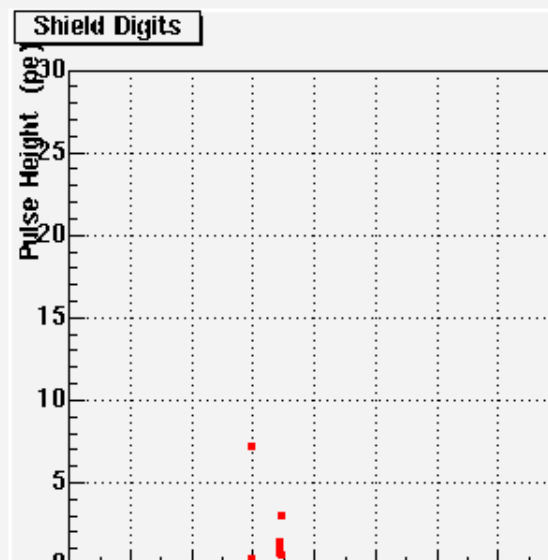
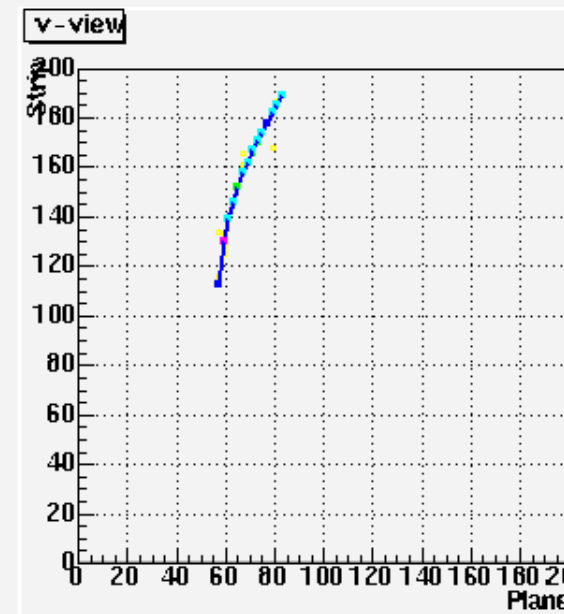
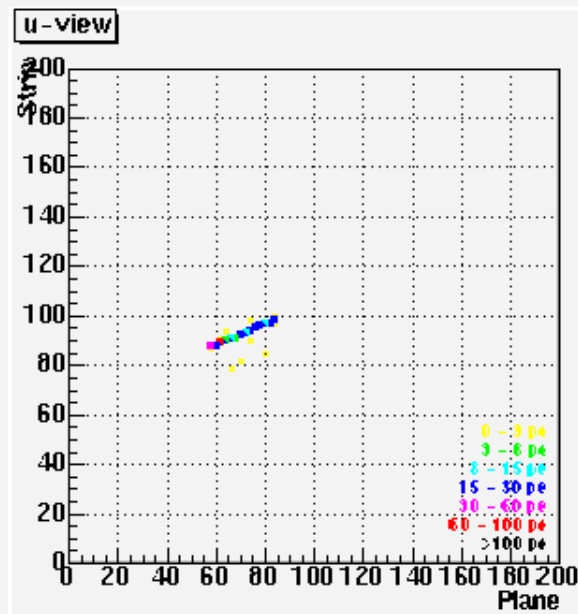
Vertex: (x,y,z) = (0.7, 4.0, 10.9)



New Demux

Run 7210, Snarl 4015

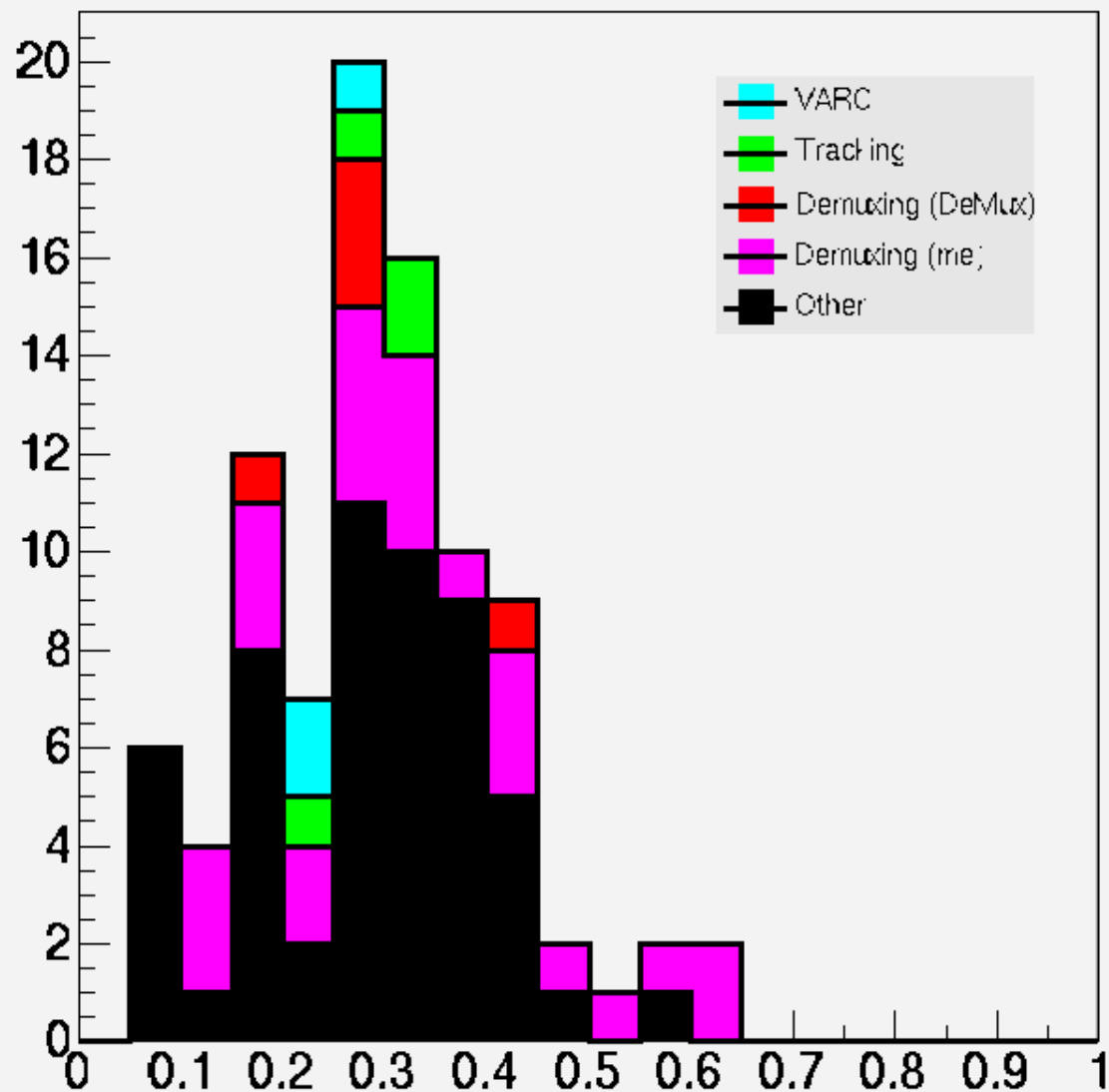
Vertex: (x,y,z) = (-2.7, 2.9, 5.0)
 $\cos(\text{zenith}) = 0.71$, $d\cos z = -0.48$



Fully Contained Events

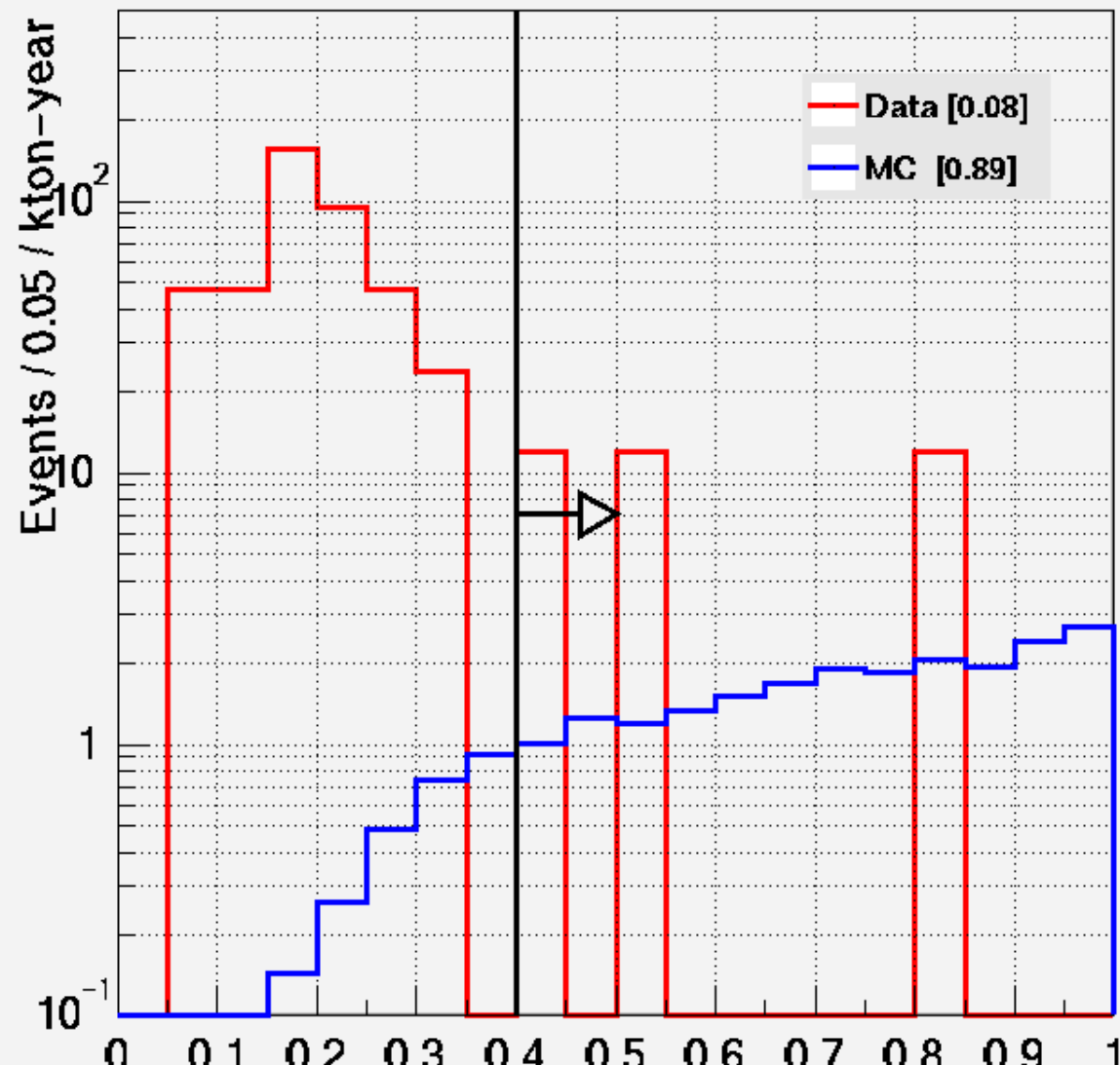
Z Direction Cosine

Z Direction Cosine



Fully Contained Event Sample
Reconstructed track, end radius < 3.5 m, 10 plane veto
timing cuts: reduced $\chi^2 < 4$, end/view times within 10 ns
nueCC/NC cuts: nplane ≥ 8 , track plane fraction > 0.7

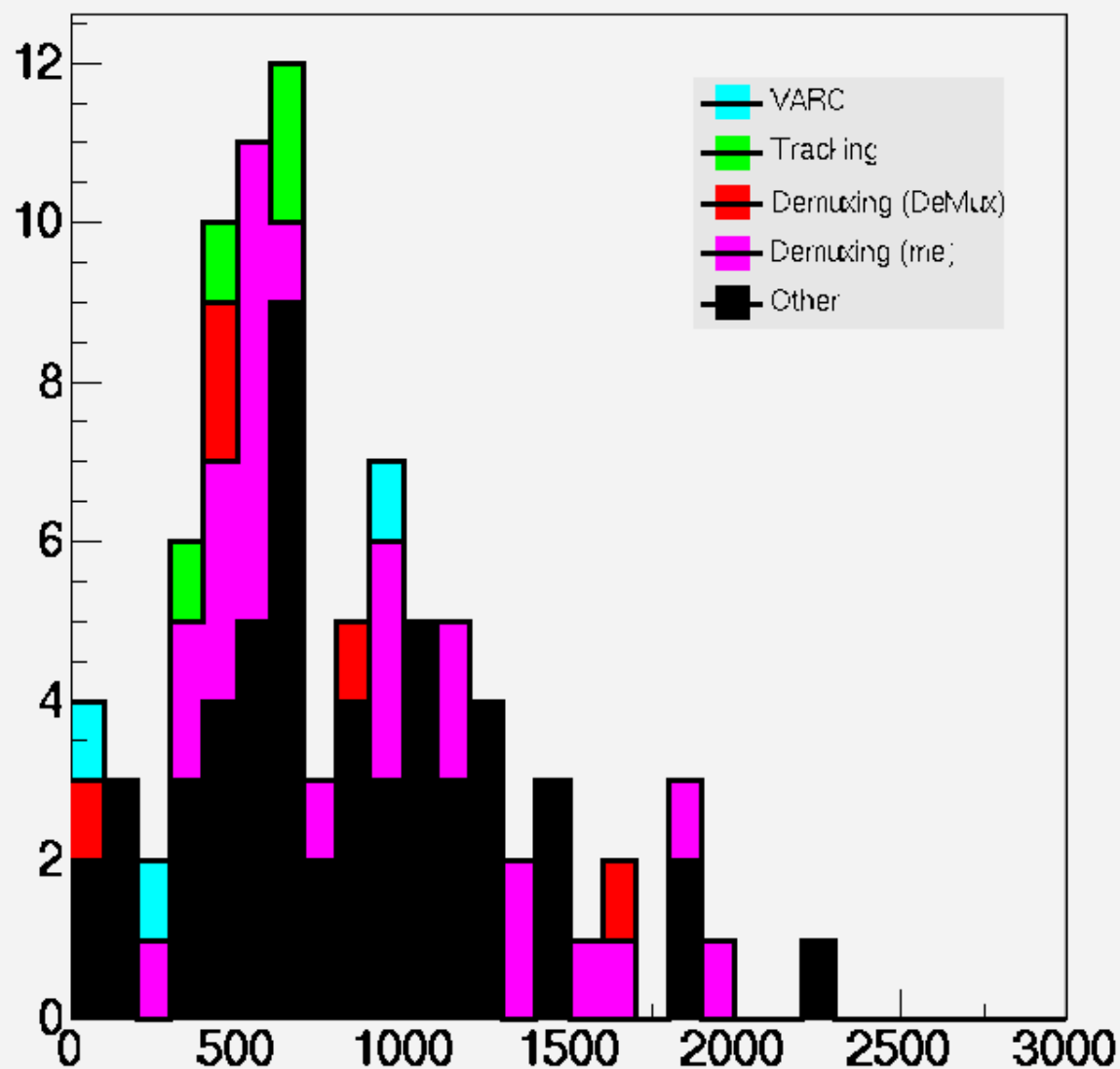
Z Direction Cosine



Fully Contained Events

Veto Shield Pulse Height

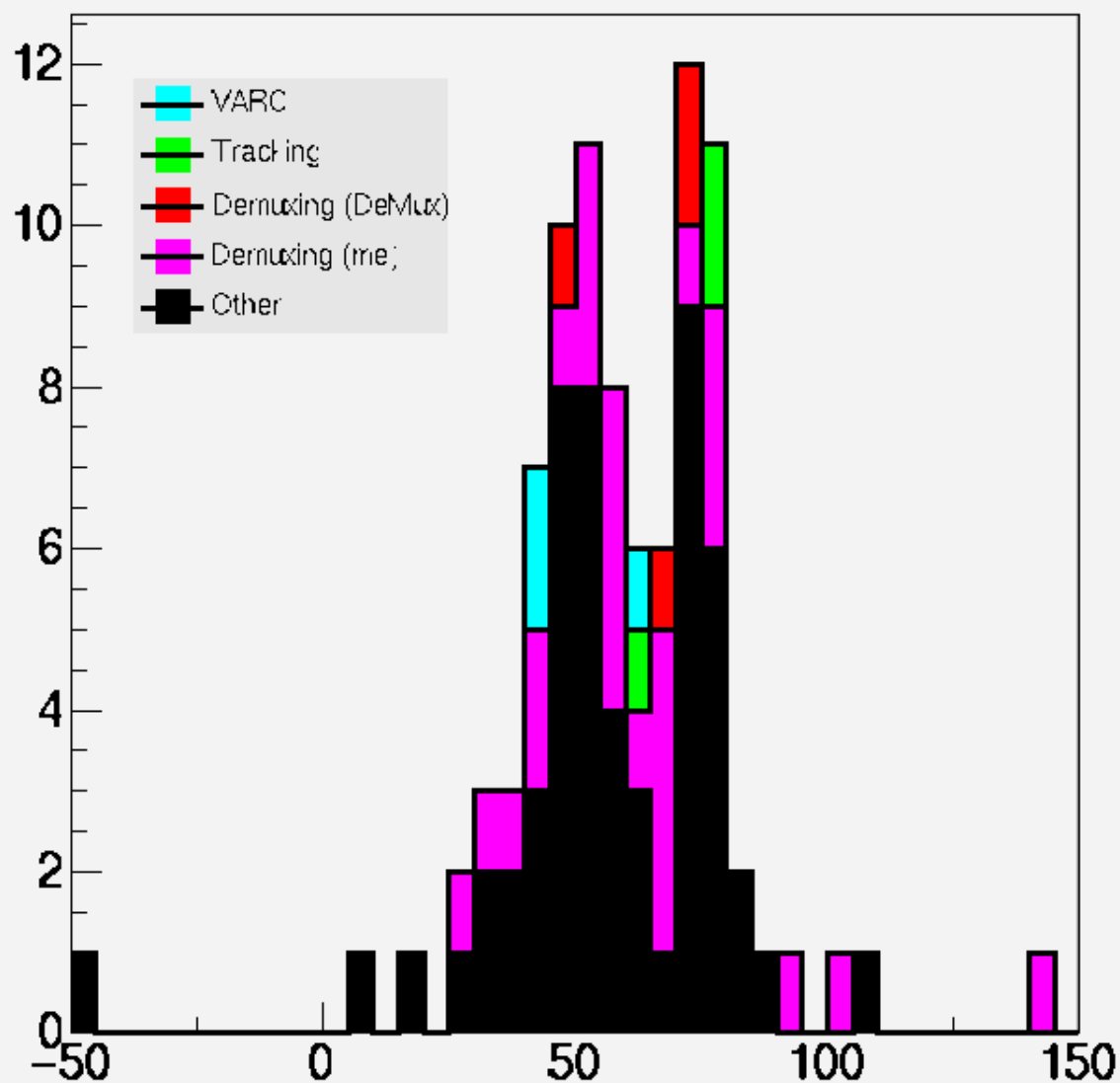
Veto Shield Pulse Height



Fully Contained Events

Veto Shield Timing

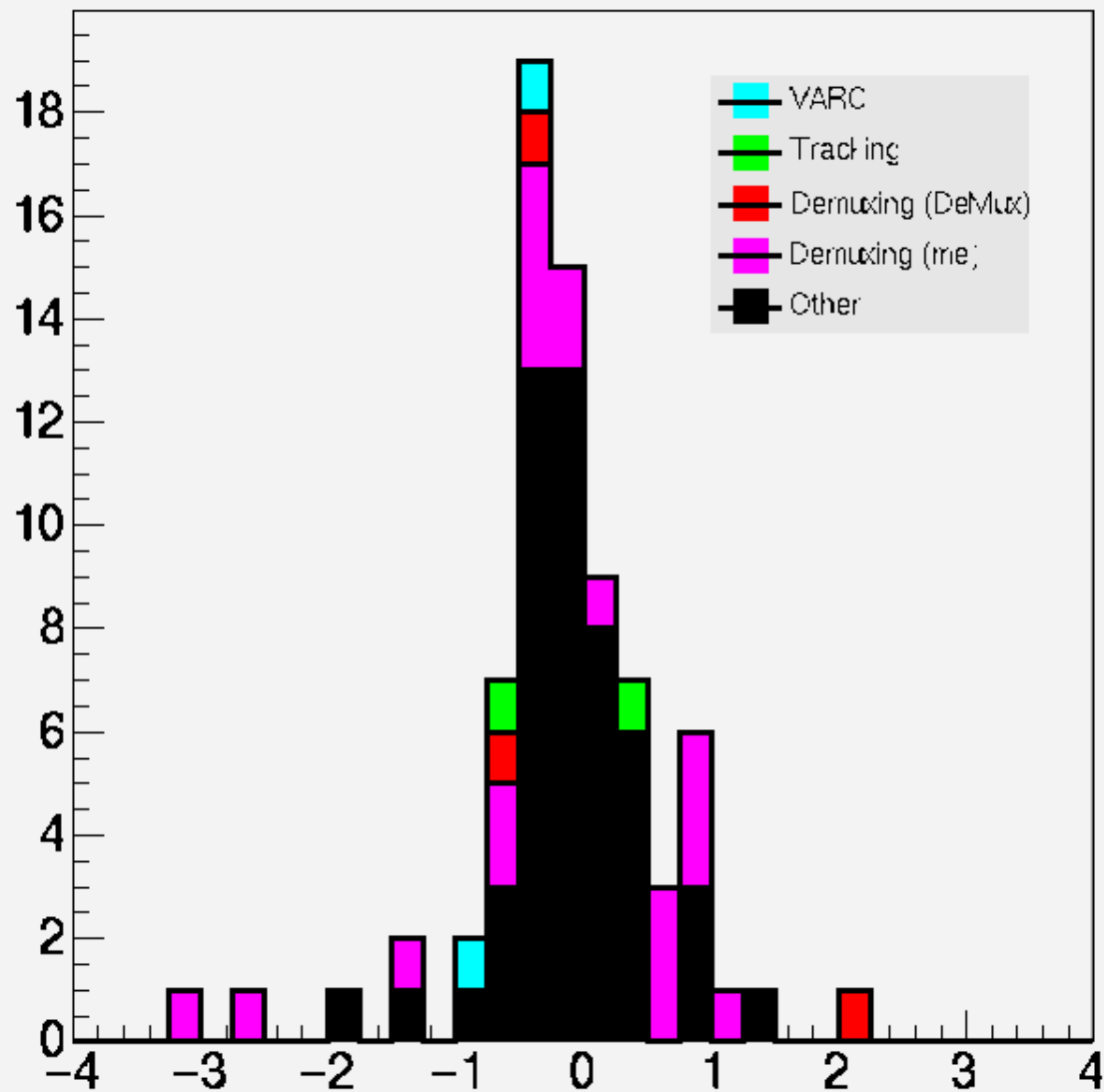
Veto Shield Time



Fully Contained Events

Top Veto Shield Spatial Residual

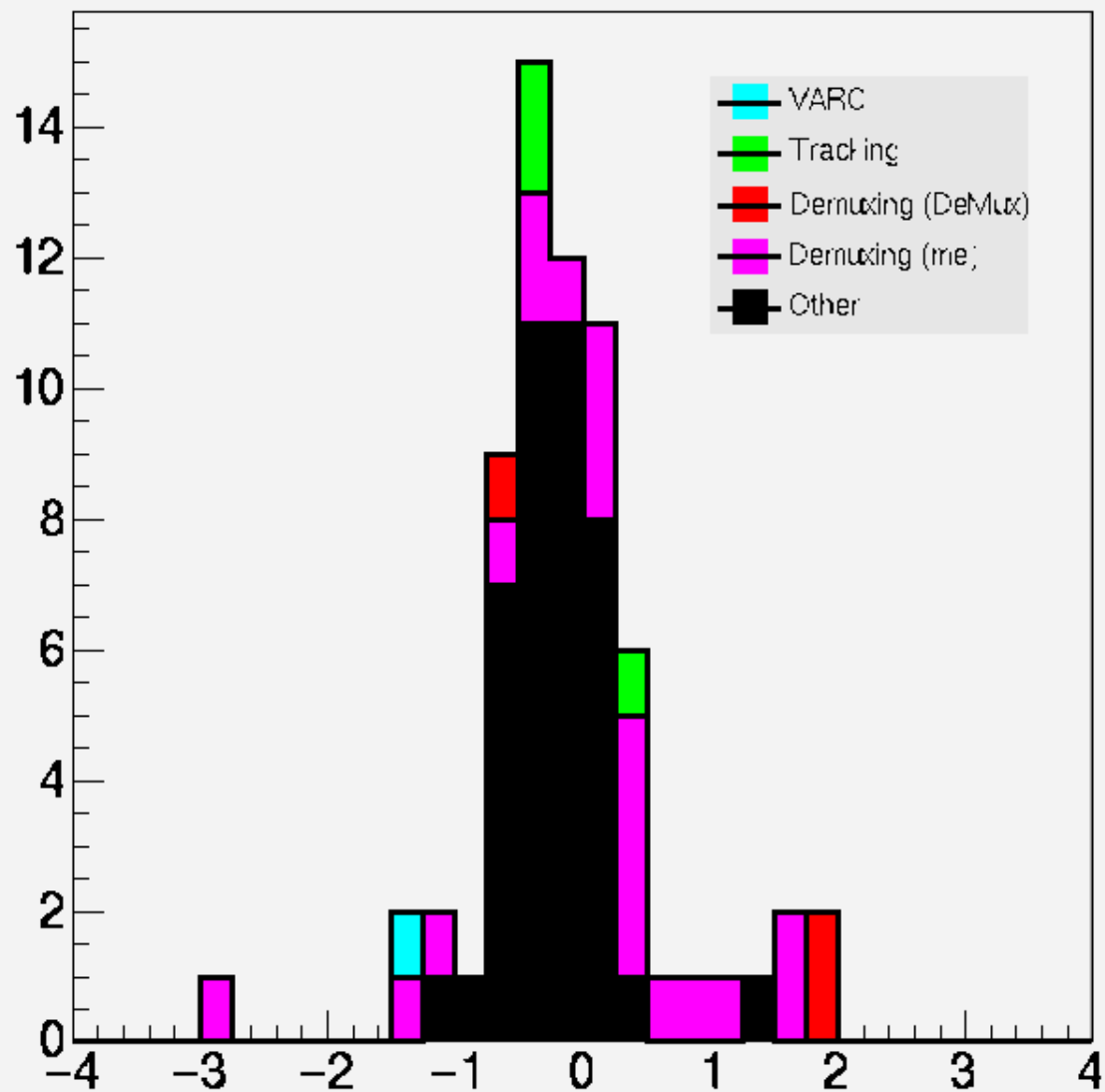
Shield Spatial Residual



Fully Contained Events

Bottom Veto Shield Spatial Residual

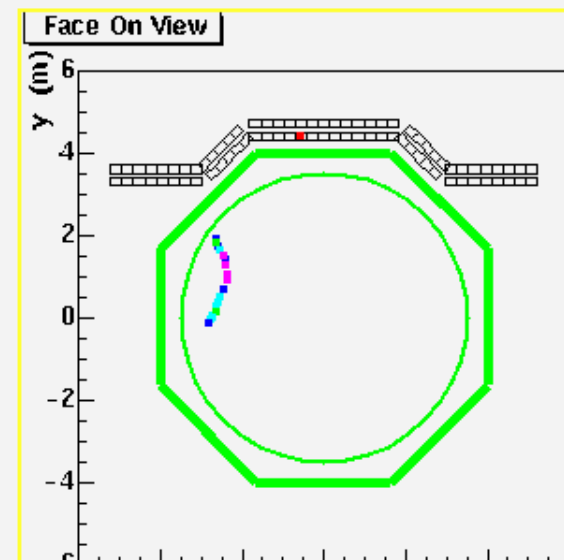
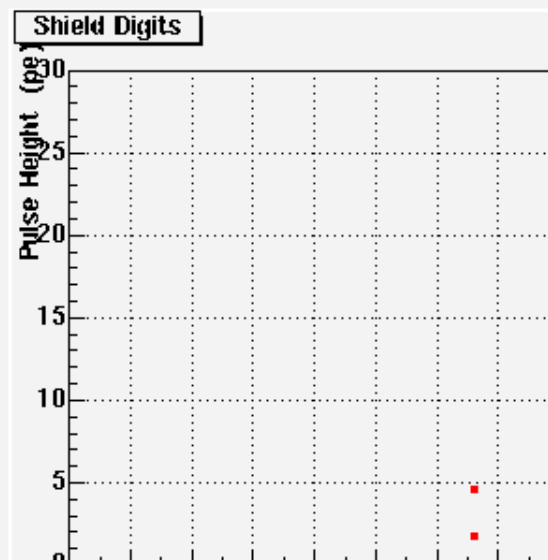
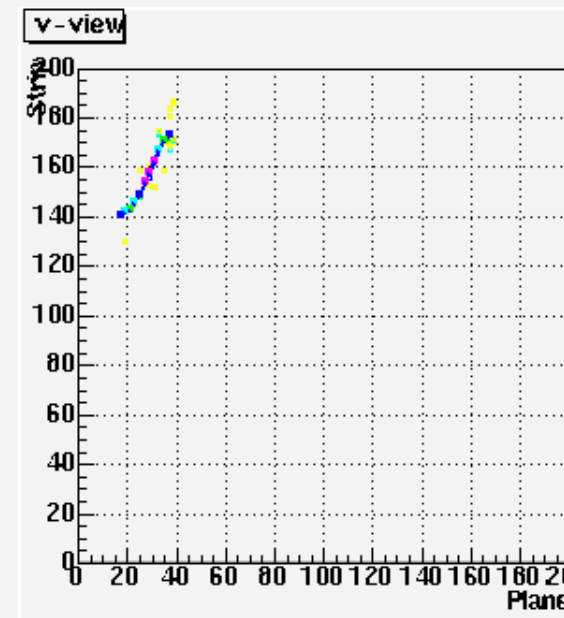
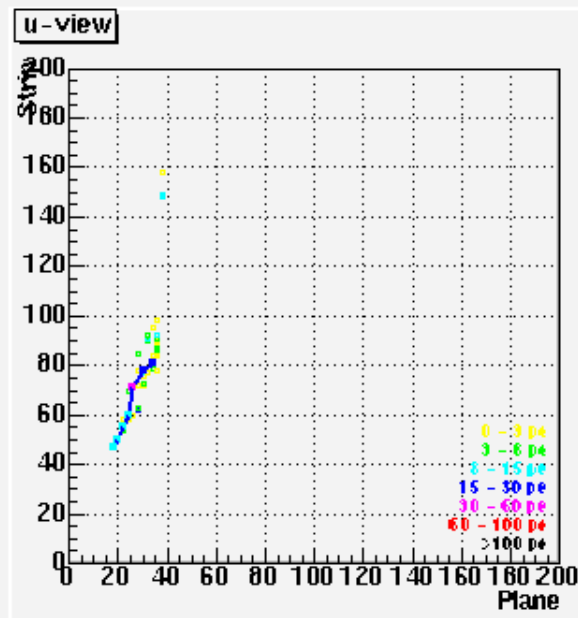
Shield Spatial Residual



Bad demux
Caught by
demuxer

Run 8052, Snarl 200173

Vertex: (x,y,z) = (-2.6, 1.9, 2.2)
cos(zenith) = 0.89, dcosz = -0.44



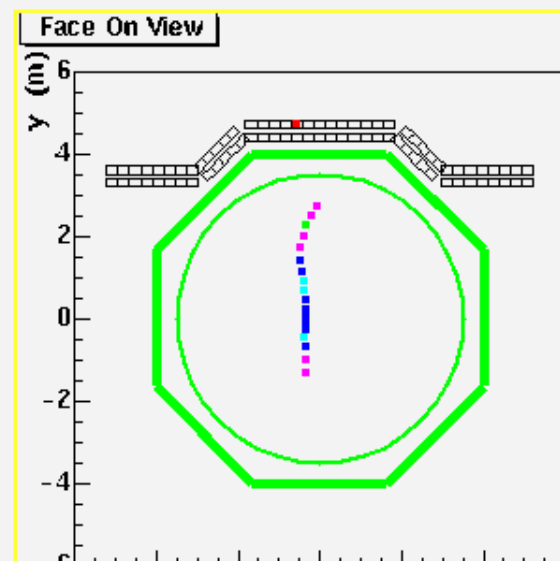
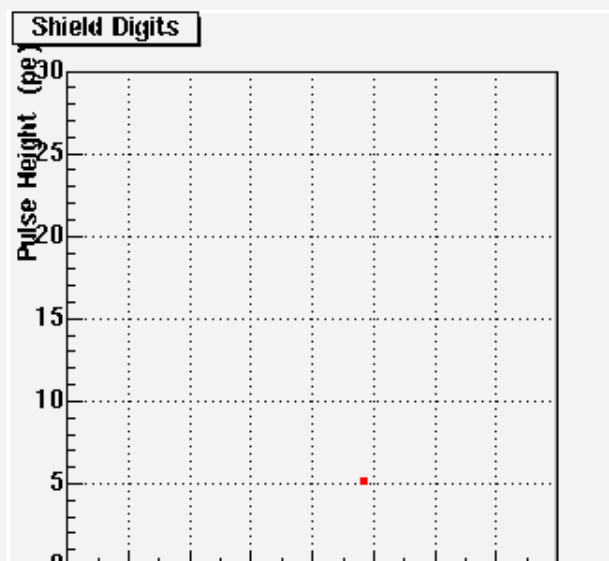
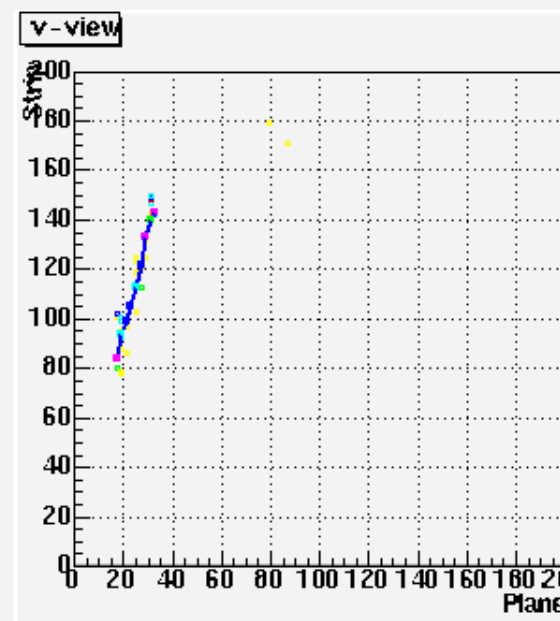
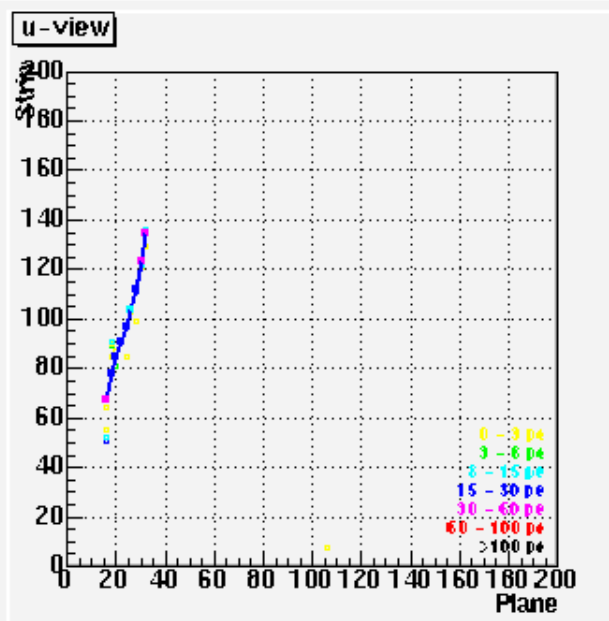
Bad demux

Not caught
by demuxer

Hits near
vertex poorly
demuxed

Run 7858, Sns1 5601

Vertex: (x,y,z) = (-0.1, 2.7, 2.0)
cos(zenith) = 0.97, dcosz = -0.25

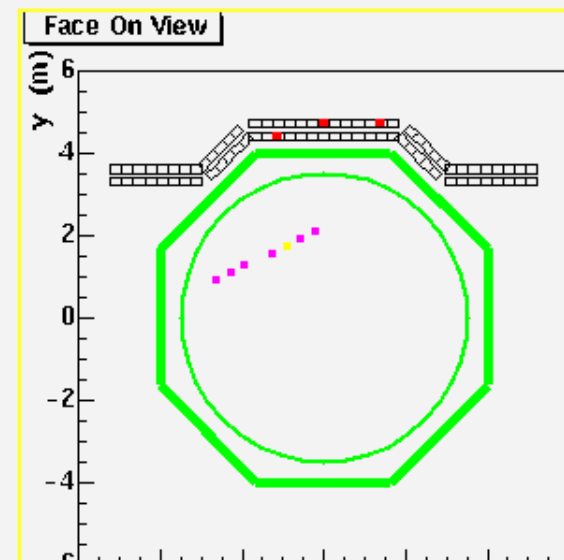
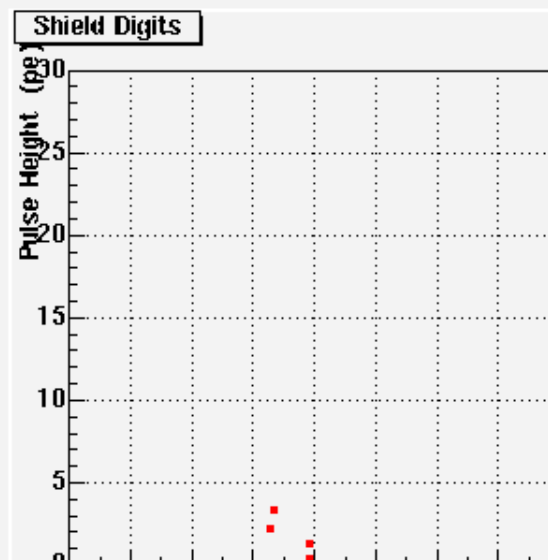
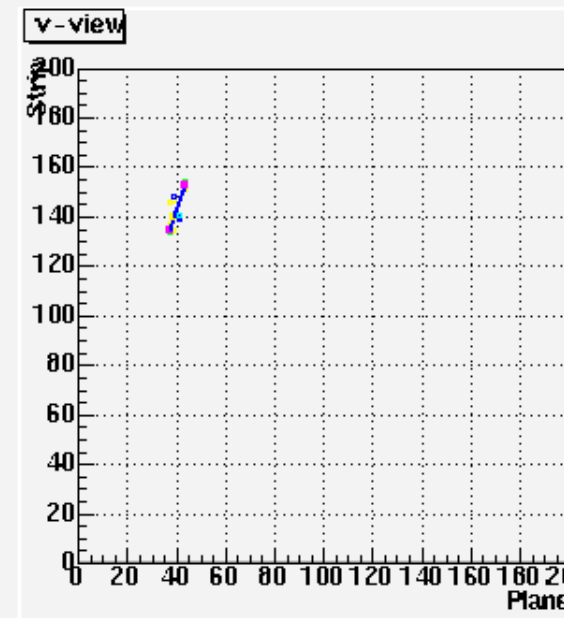
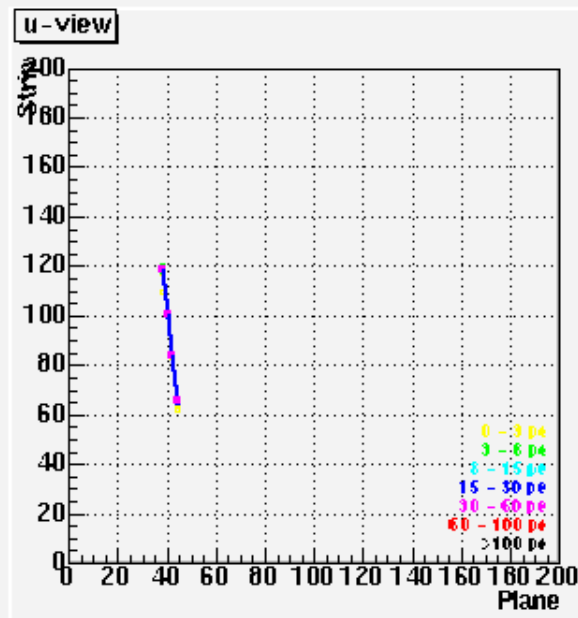


Run 7401, Snarl 65387

Vertex: (x,y,z) = (-0.2, 2.1, 2.2)
cos(zenith) = 0.43, dcosz = 0.15

Bad demux

Not caught
by demuxer



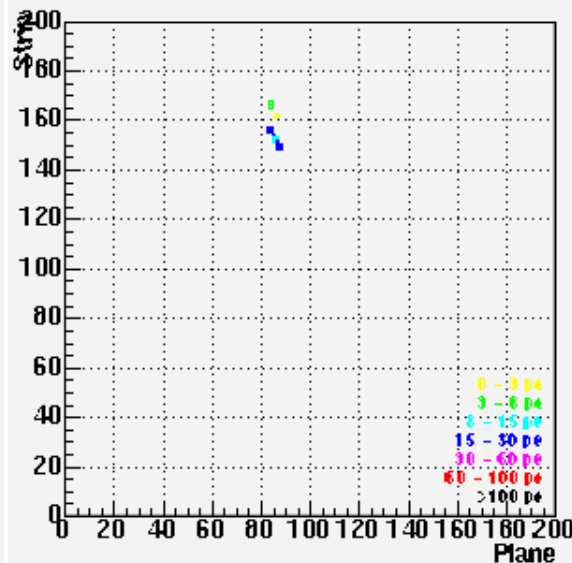
Run 7247, Snarl 7195

Vertex: (x,y,z) = (0.6, 3.3, 4.8)
cos(zenith) = 0.88, dcosz = 0.29

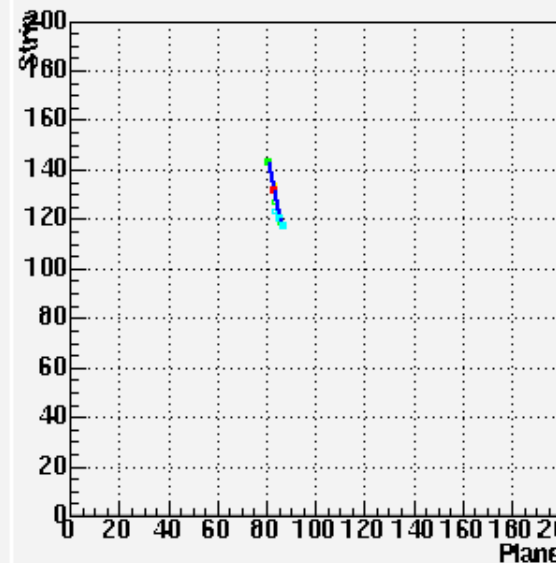
Reco ok

Track does
not point to
veto shield
hits

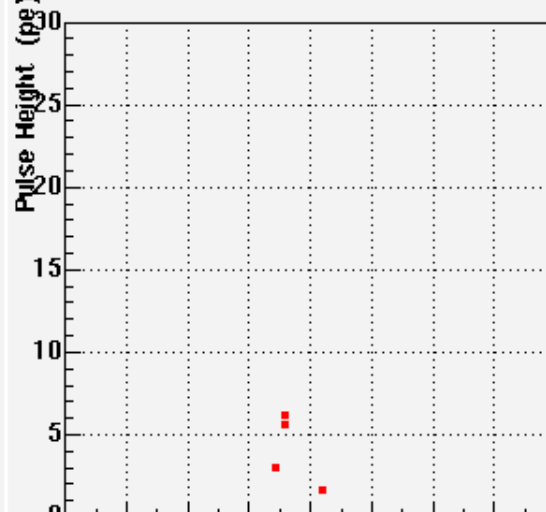
u-view



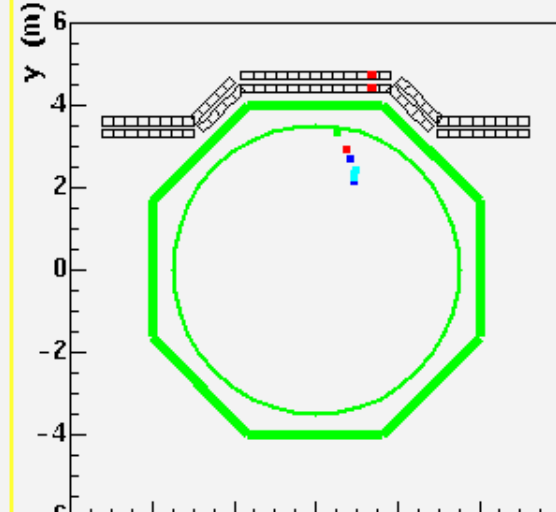
v-view



Shield Digits



Face On View



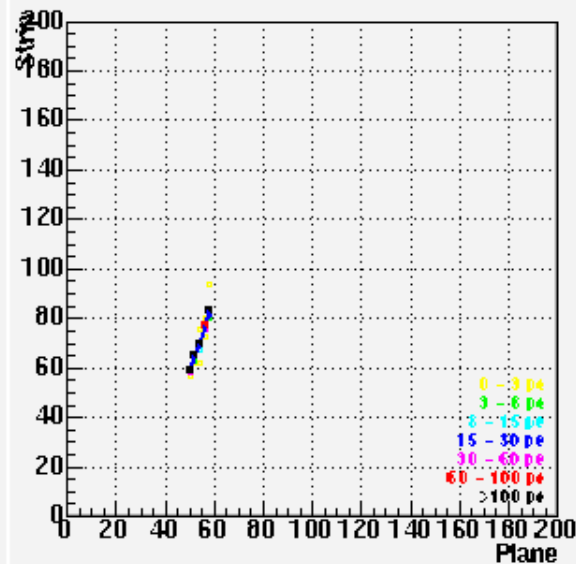
Run 7210, Snarl 29088

Vertex: (x,y,z) = (-2.7, 2.2, 3.5)
cos(zenith) = 0.81, dcosz = -0.08

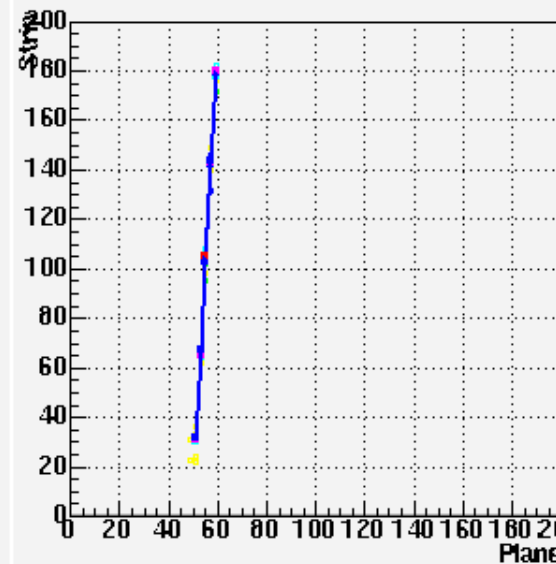
Steep angle

Easily
removed

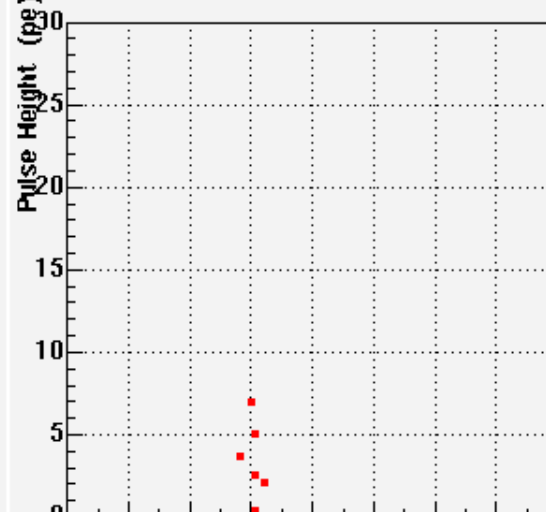
u-view



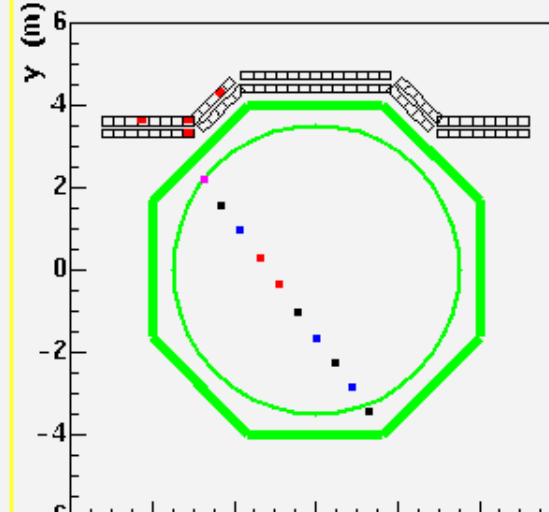
v-view



Shield Digits



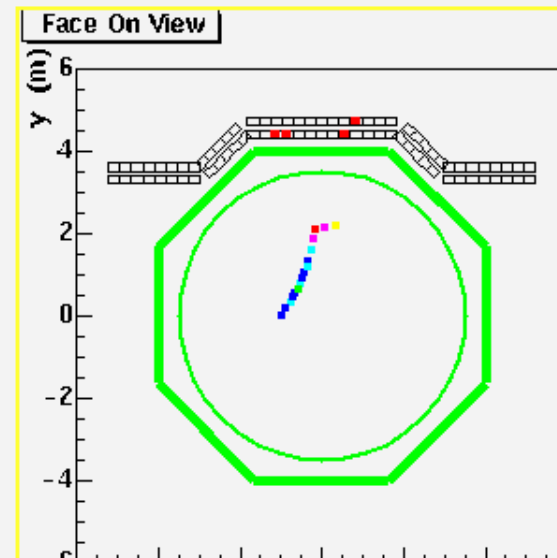
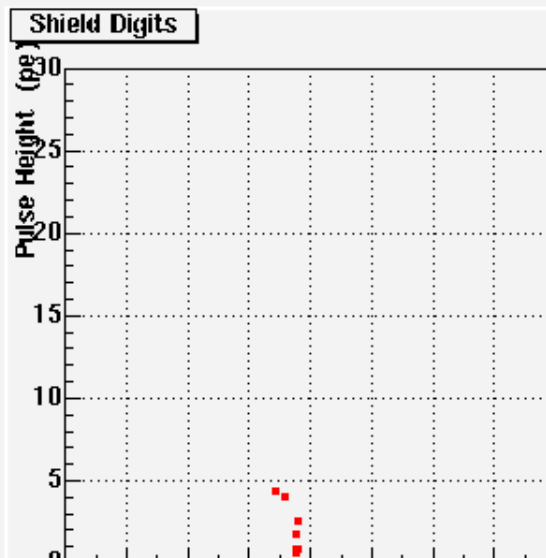
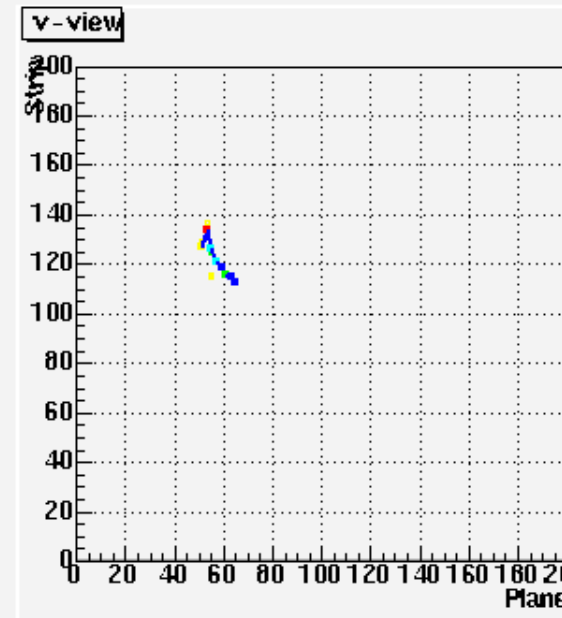
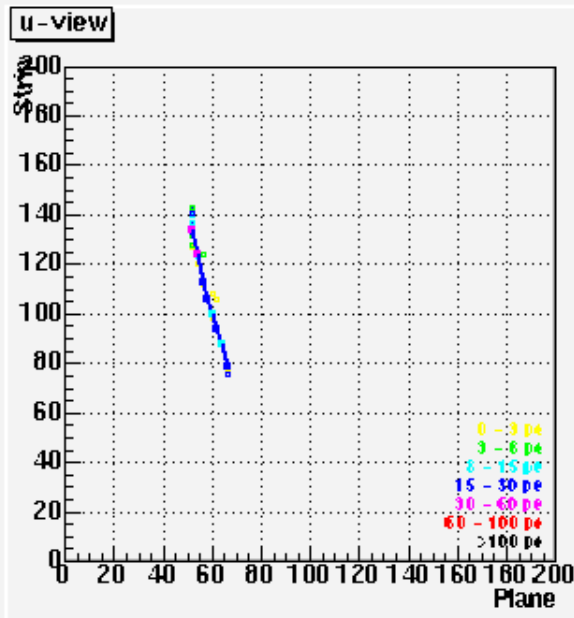
Face On View



Reco ok
35 MIPS
deposited in
first two
planes

Run 8052, Snarl 111298

Vertex: (x,y,z) = (0.3, 2.2, 3.0)
cos(zenith) = 0.85, dcosz = 0.34

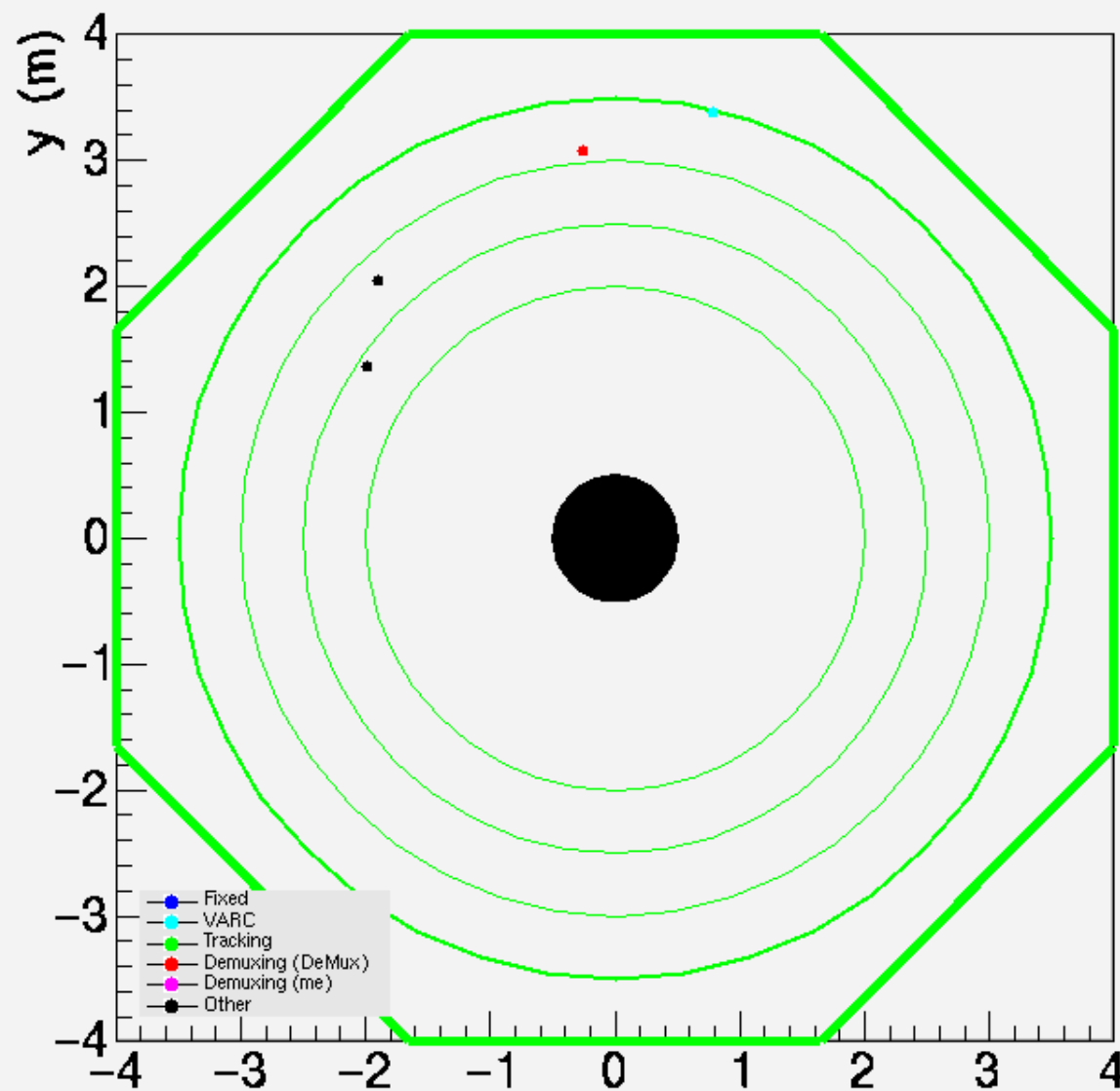


Reconstructed track, end radius < 3.5 m, 10 plane veto

Track must point back to shield

8.6 days livetime, 135 planes shield coverage, 0.6 numu CC expected

Vertex Position, Face On View

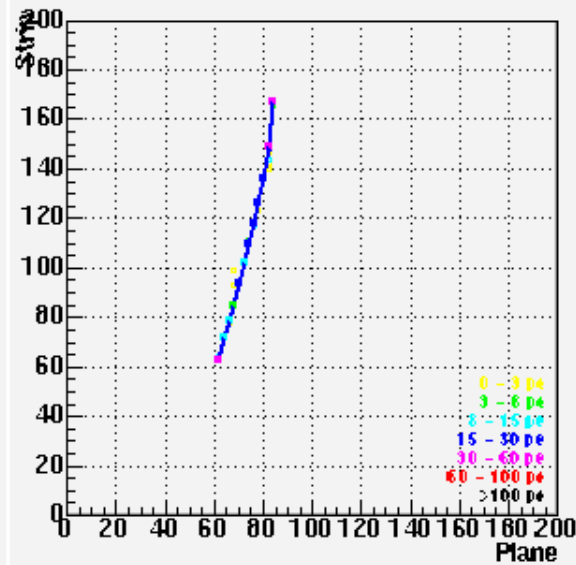


Run 7826, Snarl 16970

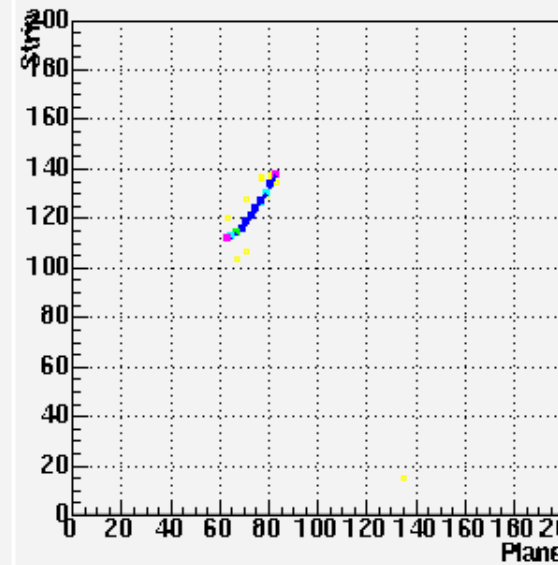
Vertex: (x,y,z) = (0.8, 3.4, 5.0)
 $\cos(\text{zenith}) = 0.84$, $d\cos z = -0.30$

Vertex at
VARC
boundary

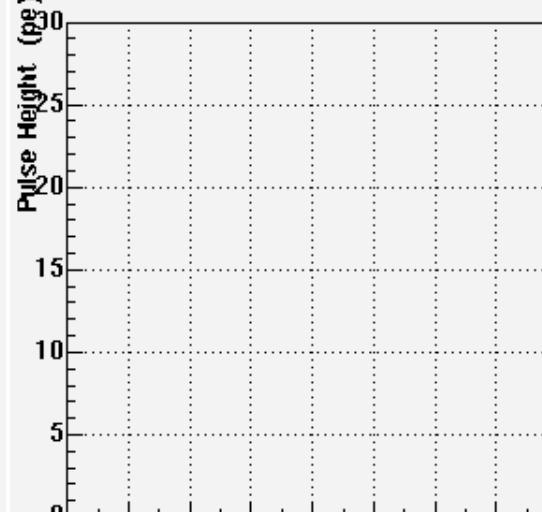
u-view



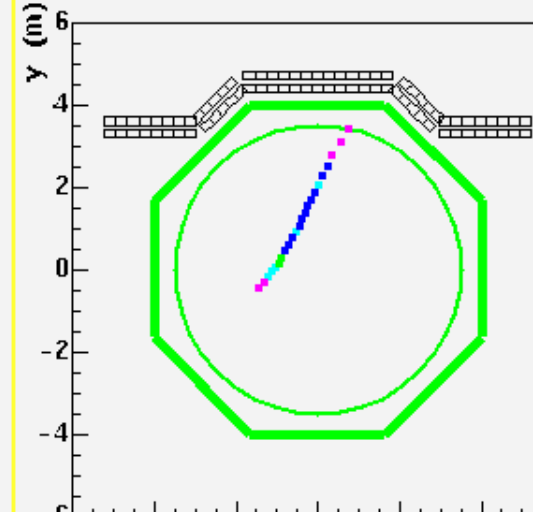
v-view



Shield Digits



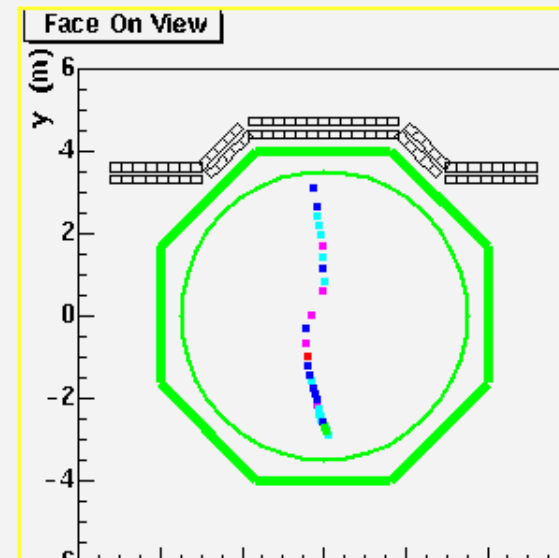
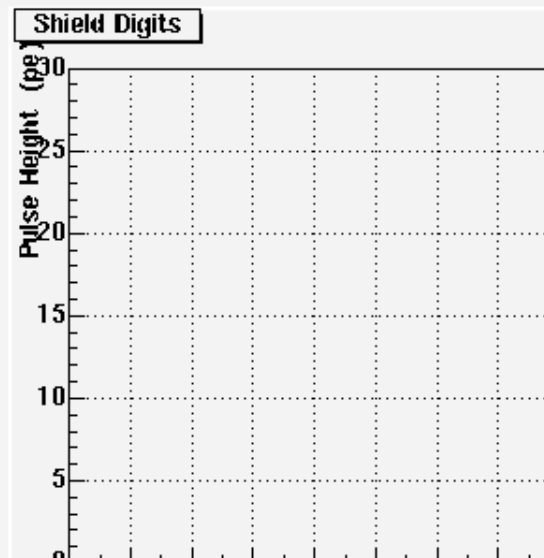
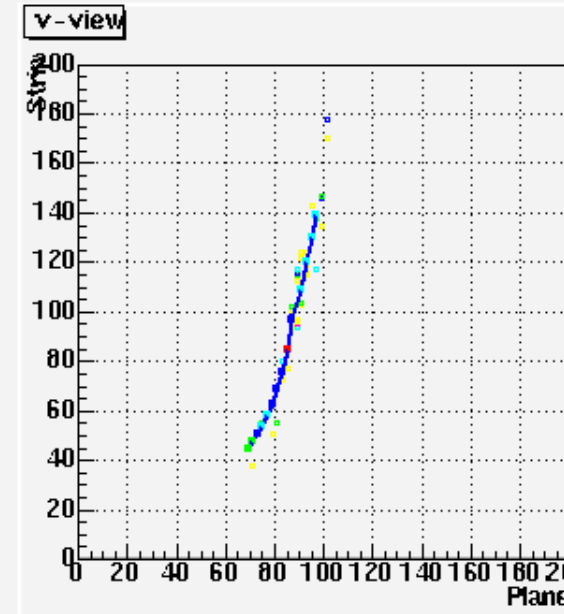
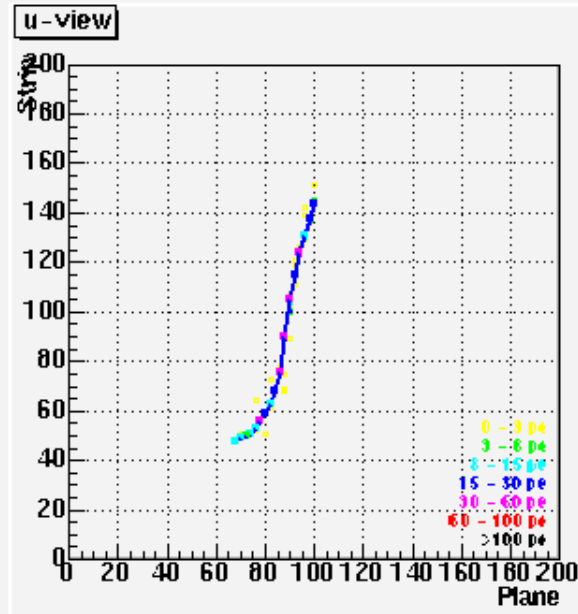
Face On View



Run 7999, Snarl 2983

Vertex: (x,y,z) = (-0.3, 3.1, 5.9)
 $\cos(\text{zenith}) = 0.96$, $d\cos z = -0.29$

Bad demux
Not caught
by
demuxer



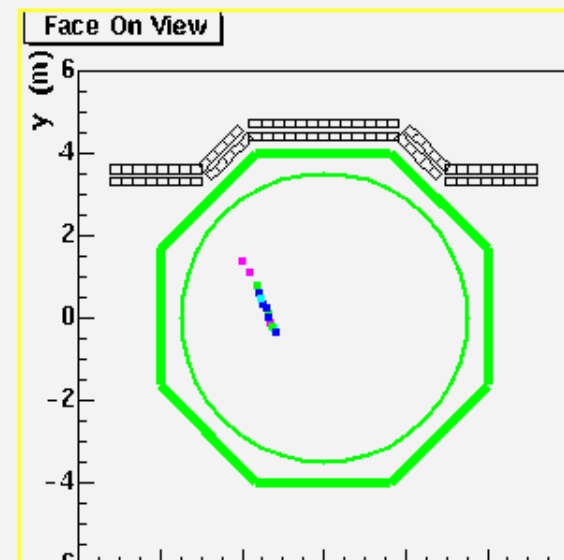
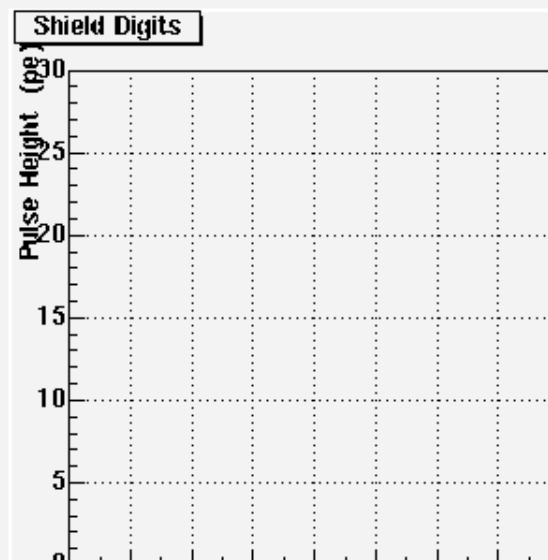
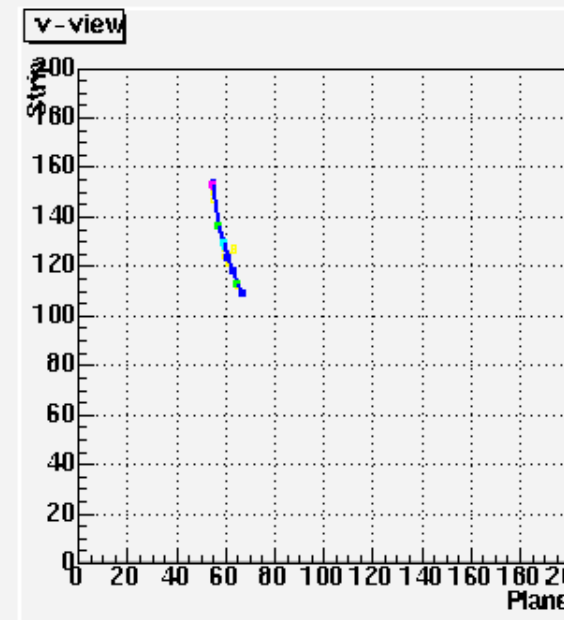
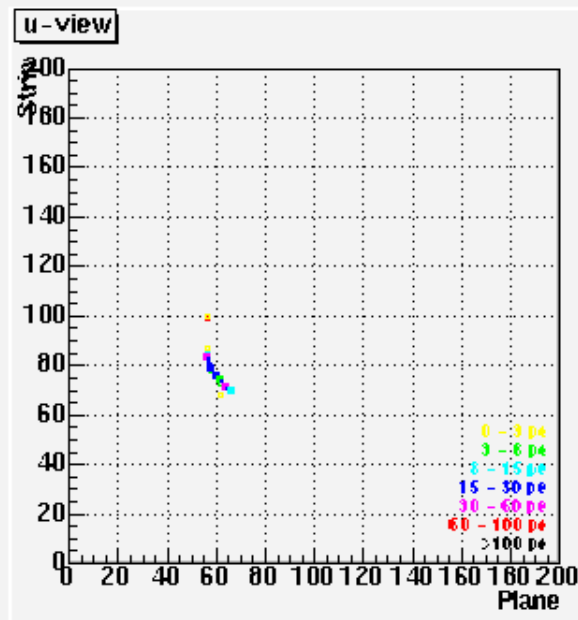
Run 8060, Snarl 42045

Vertex: (x,y,z) = (-2.0, 1.4, 3.3)
cos(zenith) = 0.85, dcosz = 0.37

Reco ok

dcosz = 0.1
at vertex

Neutrino
event?



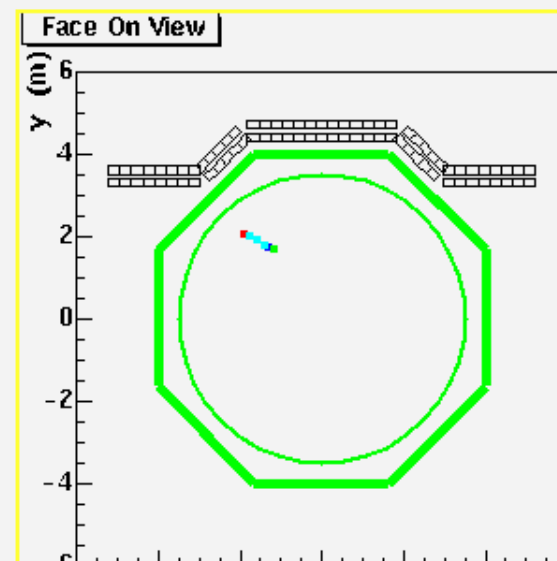
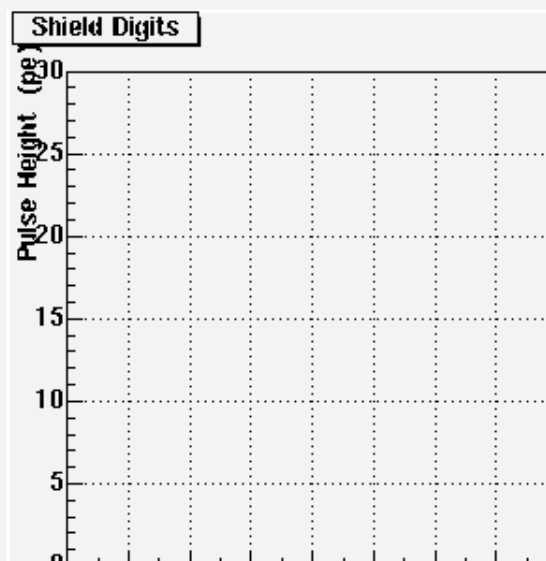
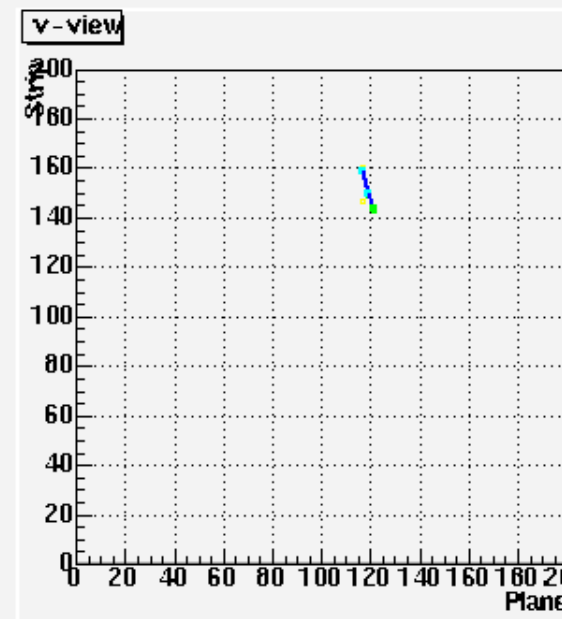
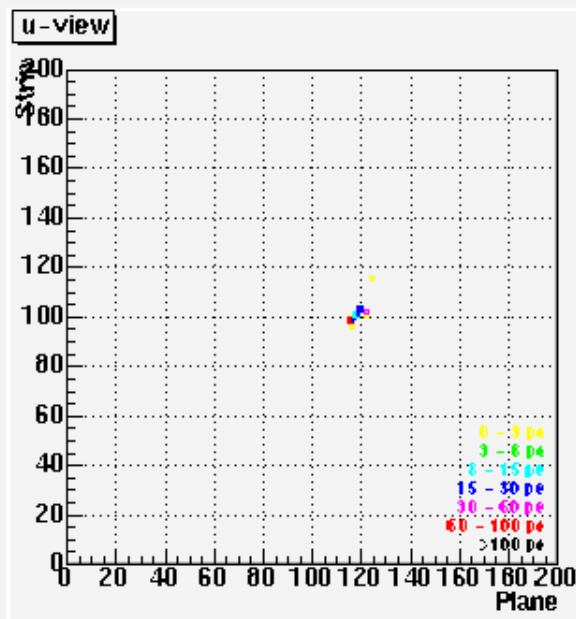
Run 7465, Snarl 412

Vertex: (x,y,z) = (-1.9, 2.1, 6.9)
cos(zenith) = 0.42, dcosz = 0.34

Reco ok

7 planes

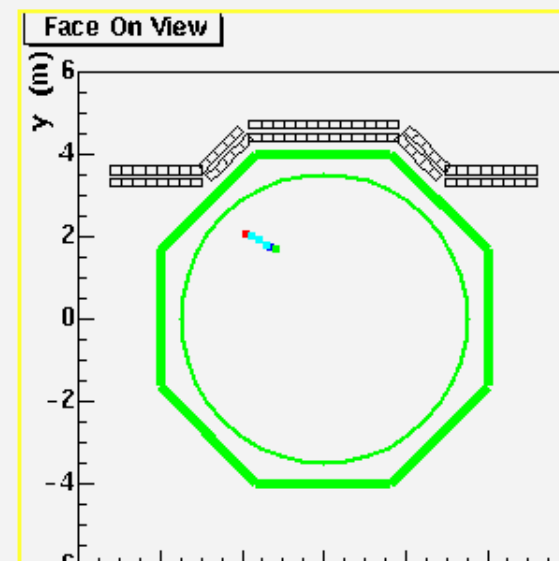
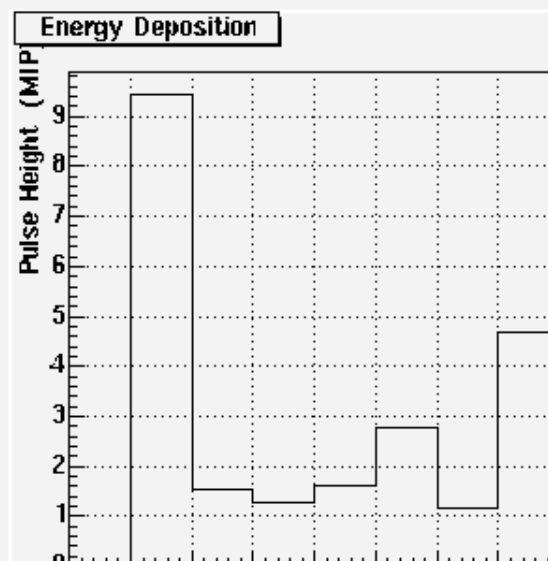
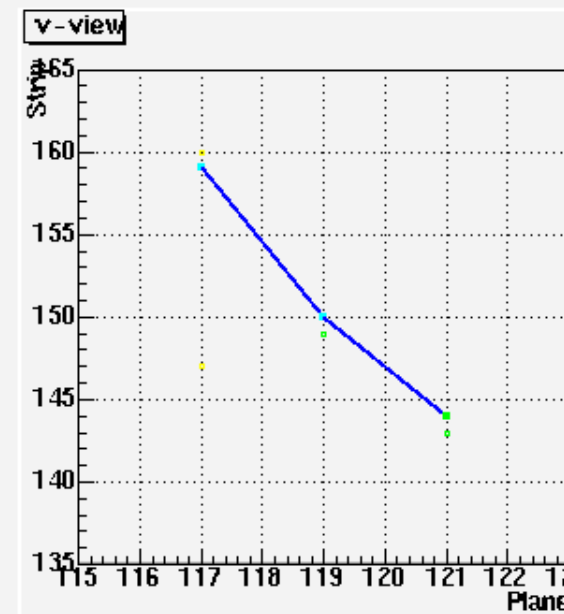
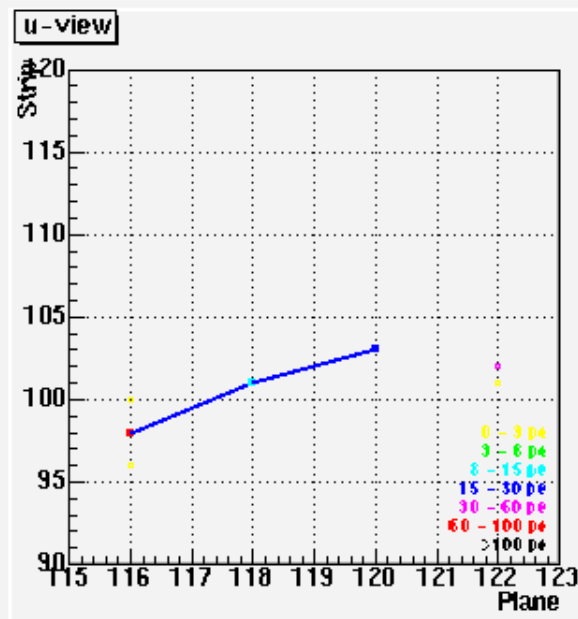
Neutrino
event?



Closer look at neutrino candidate

Run 7465, Snarl 412

Vertex: (x,y,z) = (-1.9, 2.1, 6.9)
cos(zenith) = 0.42, dcosz = 0.34

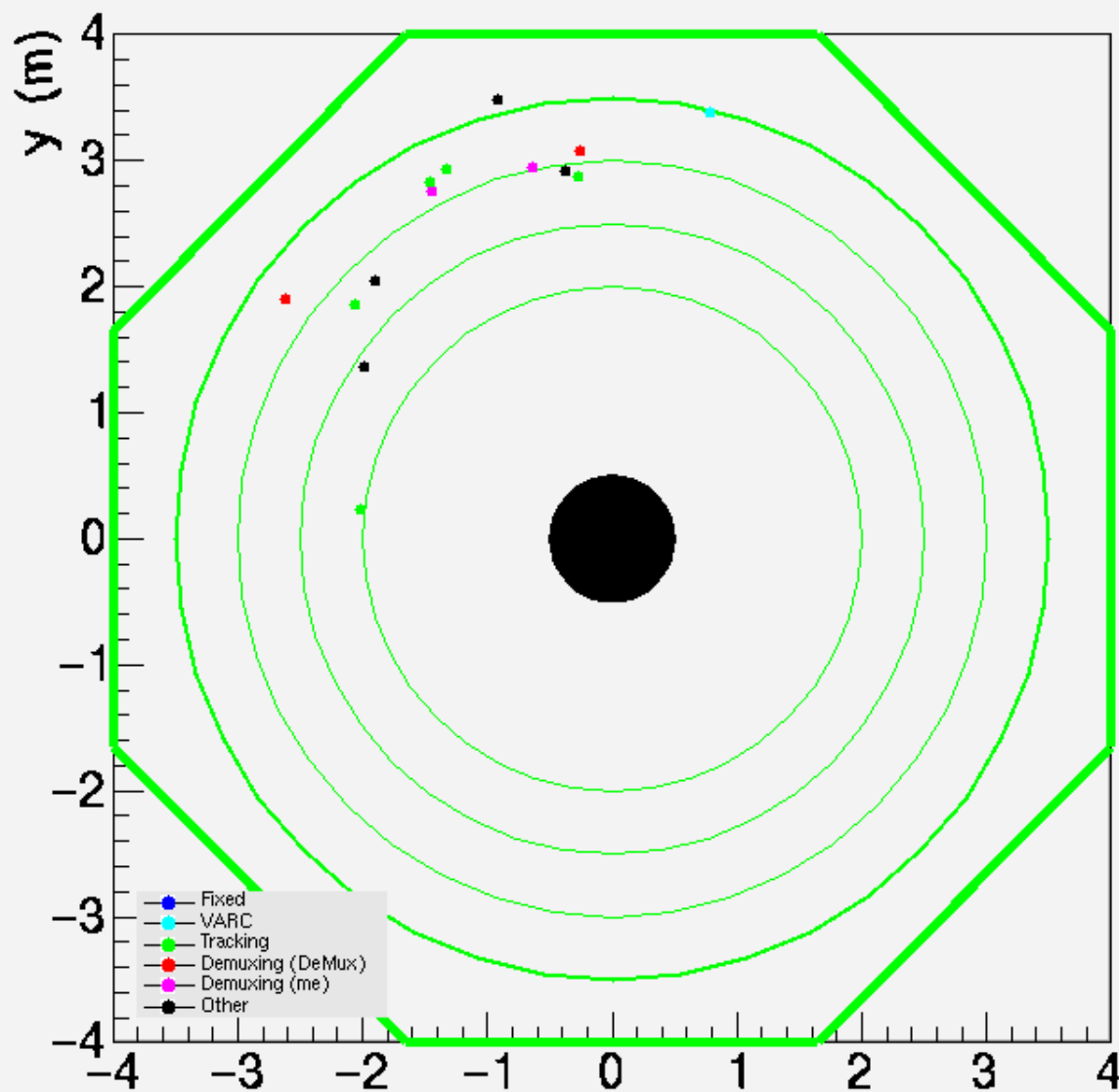


Reconstructed track, end radius < 3.5 m, 10 plane veto

Track must point back to shield

8.6 days livetime, 135 planes shield coverage, 0.6 numu CC expected

Vertex Position, Face On View



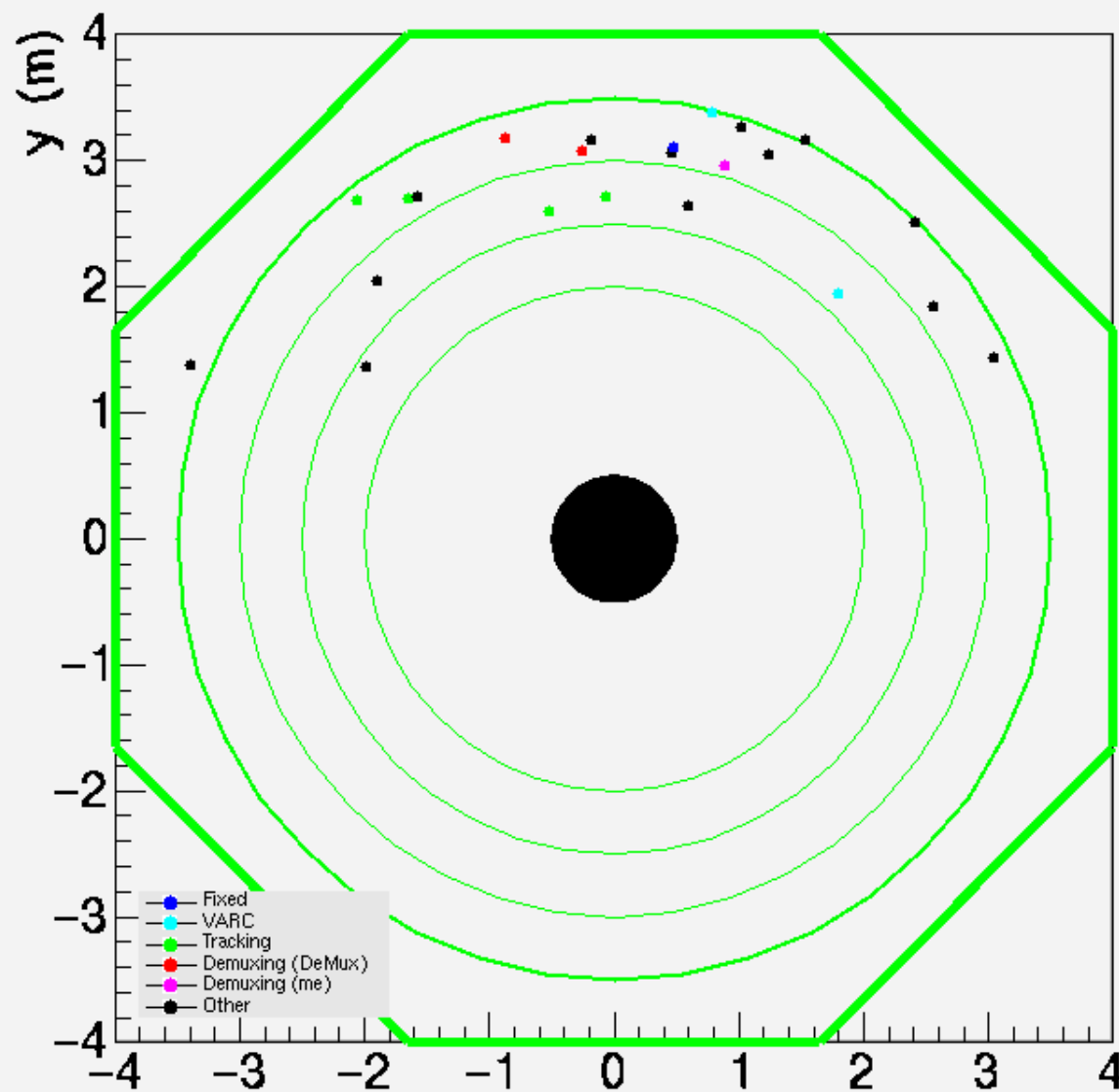
Bottom Layer Veto

Reconstructed track, end radius < 3.5 m, 10 plane veto

Track must point back to shield

8.6 days livetime, 135 planes shield coverage, 0.6 numu CC expected

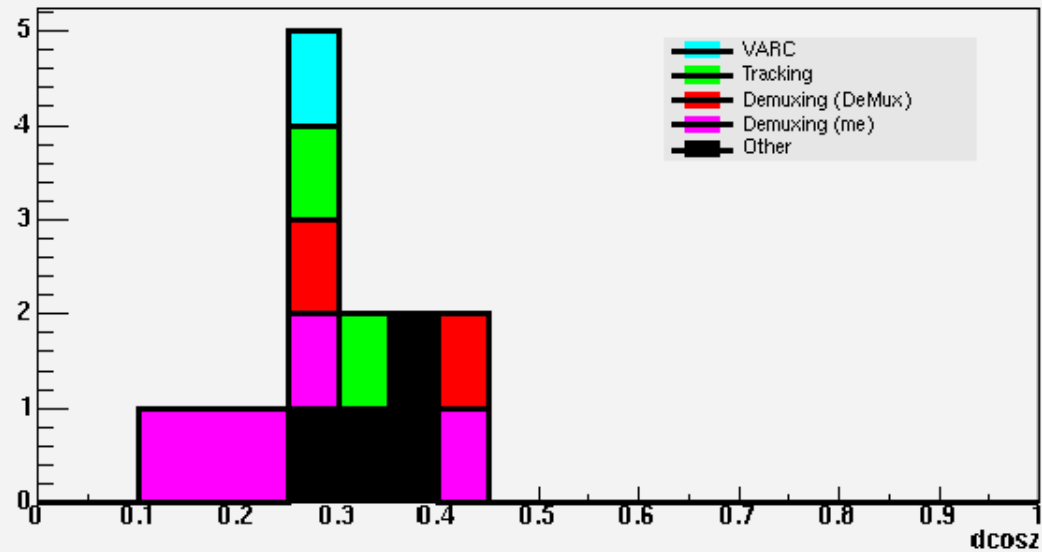
Vertex Position, Face On View



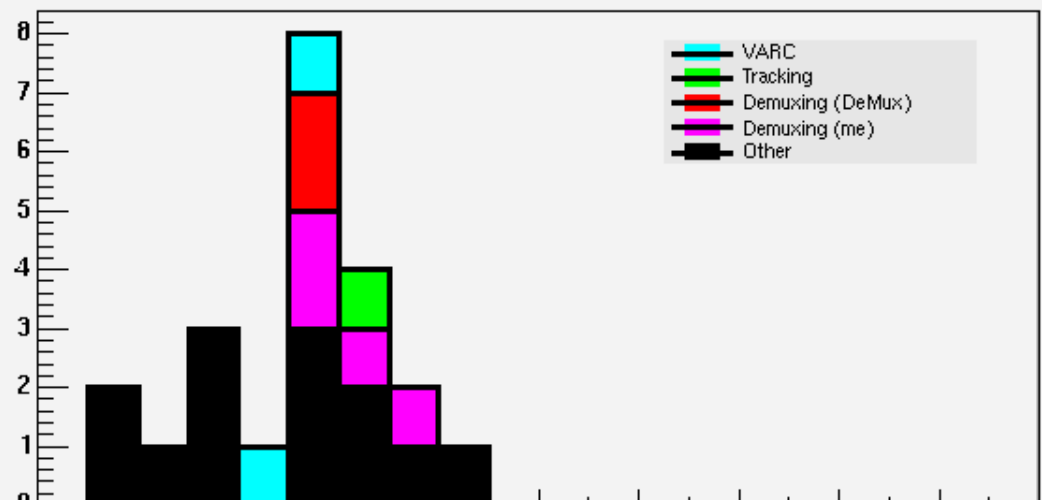
Fully Contained Events

Z Direction Cosine

Z Direction Cosine, No Top Layer Veto Hit



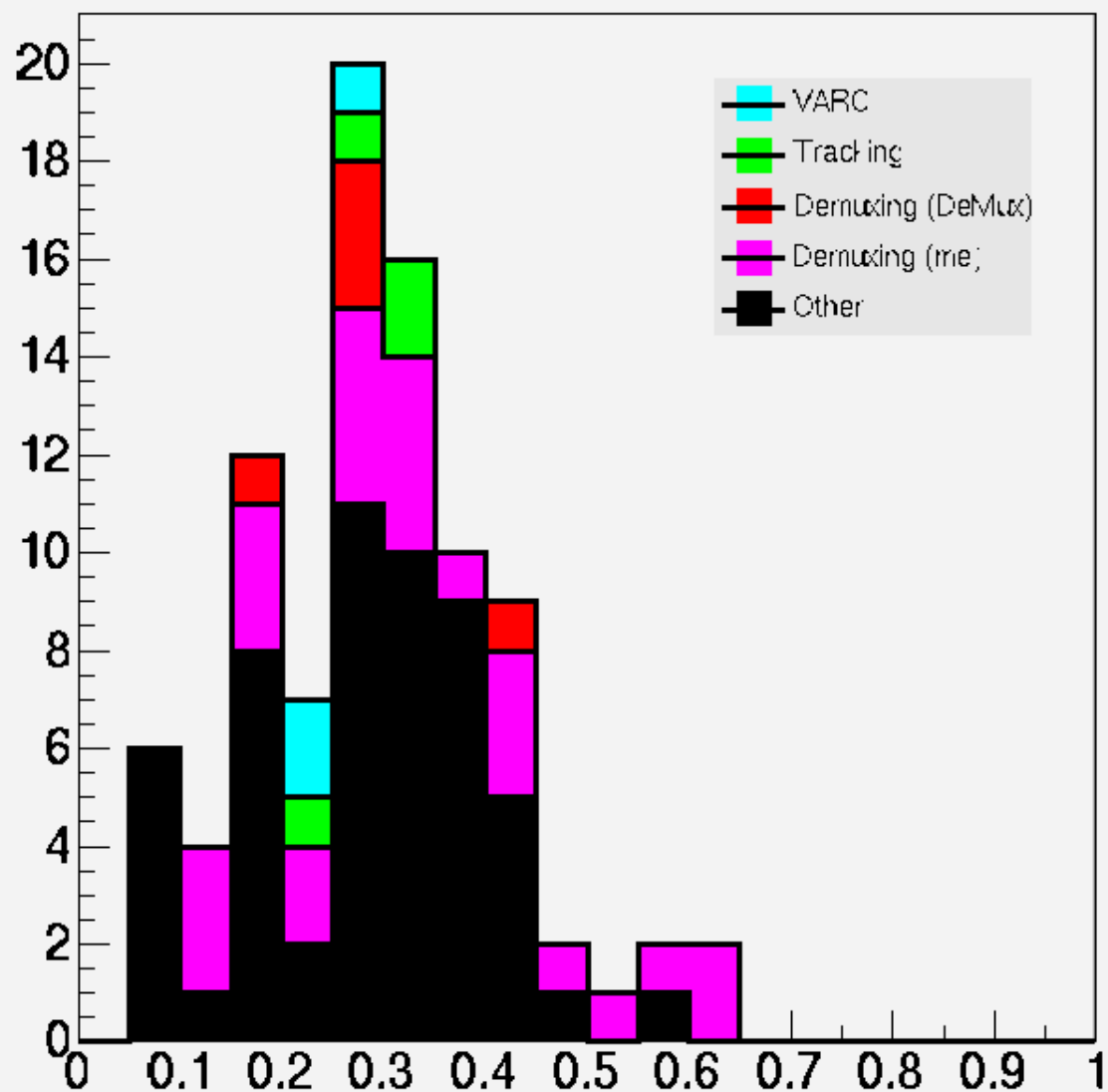
Z Direction Cosine, No Bottom Layer Veto Hit



Fully Contained Events

Z Direction Cosine

Z Direction Cosine, Ignore Shield Hits



Summary [1 / 2]

• Veto shield performance

- Single layer efficiency about 90%
- Worse for top modules than wings
- Wings have more energy deposition and shorter clear fiber lengths
- Correcting for angle and clear fiber lengths, light yield comparable to detector

Summary [2 / 2]

• Atmospheric neutrino analysis

- Background dominated by vertical muons
- More background compared to field off data
- Background suppression with single layer shield must involve kinematic cuts ($d\cos\theta$)
- 2 candidate events found (0.6 expected) with double layer shield